# Chapter 1
# Engineering Management and Intelligent Systems

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**Abstract** In this chapter we try to exhibit the relations between engineering management and intelligence and to illustrate usage frequencies of intelligent systems in engineering management. We classify the intelligent techniques since intelligent systems are the systems using these intelligence techniques. Engineering management areas such as human resources management, quality management, and strategic management have many application examples of intelligent techniques. This chapter summarizes these works briefly.

**Keywords** Engineering management · Intelligence · Intelligent techniques · Metaheuristics

## 1.1 Introduction

Engineering Management is concerned with the design, development, and implementation of integrated systems of human, machine, information, energy and material. These integrated systems are analyzed and designed with specialized engineering knowledge and skills along with other disciplines such as mathematics, physics and social sciences. The interaction of management functions namely, planning, organizing and controlling and the human factor in organizational functions such as manufacturing, finance and marketing are considered in the design, development and implementation of organizational systems. Engineering management has a wide range of areas of implementation. Some example of these areas are production, technology management, human resource management,

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finance, quality management, and service systems. Engineering management professionals should combine engineering knowledge of effectively and efficiently problem solving with business knowledge. The globalization and the rapid change in the technology increase the need of integrating managerial and engineering knowledge and skills (Damoran et al. 2014).

The engineering management problems can be simply classified as follows:

Technical Problems: problems of an engineering nature that require specialized training in personnel. Generally it is obvious when a problem falls into this category.

Personnel Problems: problems requiring decisions affecting assignment of technical responsibility and authority, organization charts, supervision assignment, and other similar matters. Later discussion will indicate the boundary of this group.

Group Problems: problems concerning sales, costs, expenditures, morale, advertising, prestige, engineering group rewards, incentive plans, etc.

These kinds of problems are tried to be solved by a wide variety of techniques from optimization techniques to engineering economic techniques or from forecasting techniques to production techniques. However, these classical techniques can be used for the solutions of neither Non-deterministic Polynomial-time hard (NP-hard) problems nor the problems with incomplete, vague and/or linguistic data. Intelligent techniques have been developed for the solution of these kinds of problems. Heuristics including intelligent search techniques are the techniques designed for solving these kinds of problems when classical methods fail for finding any exact solution. Heuristics can find exact or approximate solutions in a reasonable time frame that is good enough for solving the problem at hand.

An intelligent system is a formal or informal system to manage gathering data, processing the data, interpreting the data, and providing reasoned judgments to decision makers as a basis for action. Intelligent systems have the ability to solve complex problems, which are hard to solve by classical approaches, and they give optimum or near to optimum solutions within a reasonable time. Engineering management problems are generally complex and hard to solve by traditional methods. Biologically inspired techniques have been recently developed and used in the solutions of these kinds of problems. Metaheuristics such as ant colony optimization, genetic algorithms, artificial bee colony, etc. are intelligent techniques that we can utilize for solving engineering management problems such as maintenance management, project management, quality management, etc. Figure 1.1 represents the relationship of engineering management and intelligent techniques. Any system involving an intelligent solution technique is called an intelligent system.

The aim of this chapter is to present the place of intelligent systems in engineering management area. The rest of the chapter is organized as follows. The engineering management concept is explained in Sect. 1.2. A literature review and classification of works using intelligent systems related to engineering management are given in Sect. 1.3. Trends and future directions for intelligent engineering management are included in Sect. 1.4. The last section concludes the chapter.

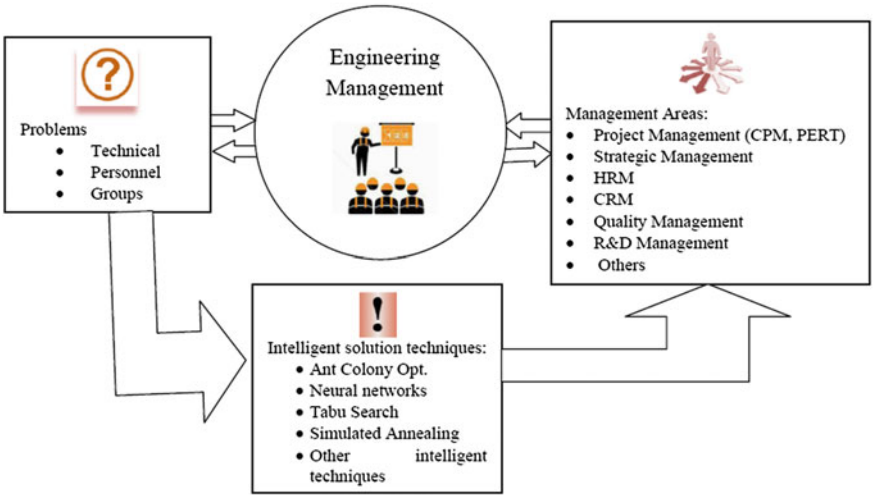


**Fig. 1.1** Engineering management problems and intelligent techniques

## 1.2 Engineering Management

The engineering management discipline does not have a unique definition, since it is a rather new, developing discipline (Xu and Li 2012). It can be defined as the combination of necessary knowledge and skills that an engineer should have in order to be successful in a managerial position (Lannes 2001). According to some researchers, the main purpose of engineering management discipline is to develop products and services which have certain requirements, budget, schedule and risk by using system engineering (Shaw 2002). Engineering Management is also defined as the discipline that focuses on the decision making process for the current and new technologies and impact on interrelated systems (Kocaoglu 2002). Although there are different definitions of Engineering Management, the objective of engineering management discipline can be defined as to apply engineering principles to the business practices. This discipline handles complex managerial and organizational problems with engineering problem solving tools and techniques. These managerial problems involving both people and technology are handled with engineering analysis, design and control processes. Engineering management discipline necessitates both management knowledge and engineering knowledge. Measurement, result orientation, application and technology usage are the main characteristics of engineering discipline. Along with these engineering characteristics, system thinking, systematic approach, modeling and human orientation are the main dimensions of engineering management discipline.

The engineering management discipline has a variety of study areas. Risk management, knowledge management, management and organization, production management, economic and financial management, quality management, marketing and

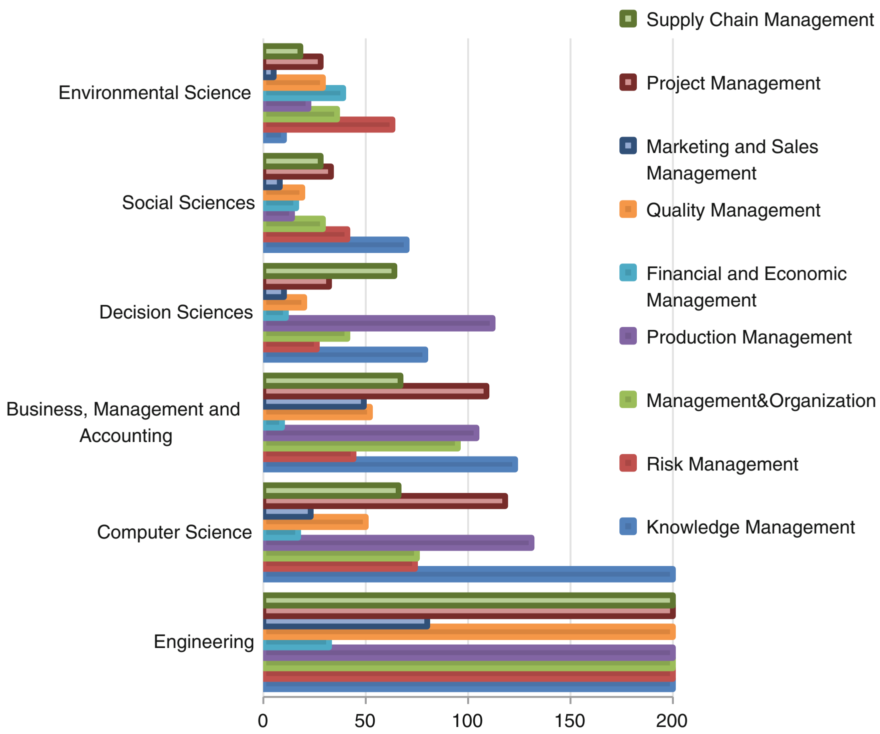


**Fig. 1.2** Engineering management study areas and their application fields

sales management, project management, and supply chain management are the main areas that can be analyzed with engineering management perspective. Figure 1.2 shows the results of literature survey using SCOPUS, it illustrates main engineering management study areas and their most commonly applied problem fields.

Knowledge management is the process of effectively managing organizational knowledge. The problems such as strategic software design, innovation strategy selection, and research and development strategy definition are the examples of knowledge management problems that can be solved with engineering management perspective. A literature review for knowledge management with engineering management perspective using SCOPUS gives 495 published papers. Knowledge management with engineering management perspective has been used in different areas such as computer science, engineering, mathematics, business management and accounting, decision sciences, environmental science and social sciences. Knowledge management with engineering management perspective is mostly used for solving engineering and computer science related problems (Fig. 1.2).

Risk management is the process of identifying, evaluating and taking necessary cautions for unwanted events. A literature review for risk management with engineering management perspective using SCOPUS gives 412 published papers and this approach has been used in various areas. The risk management problems in engineering, computer science and environmental science are largely handled with engineering management perspective (Fig. 1.2).

Organizing, leading, planning and controlling are the main functions of management. Engineering approaches can be applied for solving managerial and organizational problems. A literature review for management and organization with engineering management perspective using SCOPUS gives 476 published papers. The strategic management problems, human resource problems and organizational design problems can be solved with engineering management perspective.

Production management focuses on efficiently and effectively converting raw materials into finished goods or products. Facility location and plant layout, maintenance planning and management and materials management are the examples of production management problems that can be solved with engineering management perspective. A literature review for production management with engineering management perspective using SCOPUS gives 597 published papers. Production management with engineering management perspective is mostly used for solving engineering, decision science and computer science related problems (Fig. 1.2).

Financial management and managerial economics try to plan, organize, lead and control financial and economic activities. The engineering perspective improves the problem solving capability of these discipline. A literature review for financial management and managerial economics with engineering management perspective using SCOPUS gives 104 published papers. Financial management and managerial economics with engineering management perspective are mostly used for solving environmental science, engineering, and computer science related problems (Fig. 1.2).

Quality management focuses on maintaining the consistency of the business products, services and the processes. Both the quality services such as developing quality plans, quality control and quality improvement and the approaches such as total quality management have strong ties with engineering management discipline. A literature review for quality management with engineering management perspective using SCOPUS gives 325 published papers. Quality management with engineering management perspective is mostly used for solving engineering, business and computer science related problems (Fig. 1.2).

Marketing and sales management try to plan, organize, lead and control marketing and sales activities of an organization. The marketing and sales resources are managed with the marketing methods and techniques. Engineering management discipline improves these techniques. A literature review for marketing and sales management with engineering management perspective using SCOPUS gives 153 published papers. Marketing and sales management with engineering management perspective are mostly used for solving engineering and business related problems (Fig. 1.2).

A project is a non-routine, one time effort with specific requirements and has budget, time and resource constraints. Project management focuses on planning, organizing, leading and controlling the project related activities. Project planning and project performance evaluation are the examples of the problems in project management that can be improves with engineering management approach. A literature review for project management with engineering management perspective using SCOPUS gives 533 published papers. Project management with engineering management perspective is mostly used for solving engineering, business and computer science related problems (Fig. 1.2).

Supply chain management is the process of managing material and information flow from supplier to the end customer. Logistics management, vehicle routing and warehouse management are some supply chain management problems that can be improved with engineering management. A literature review for supply chain management with engineering management perspective using SCOPUS gives 302 published papers. Supply chain management with engineering management perspective is mostly used for solving engineering, business, computer science and decision science related problems (Fig. 1.2).

## 1.3 Intelligent Systems

Intelligent systems (IS) are able to handle more complex situations and make more complex decisions. IS includes a range of techniques that provide flexible data/information processing capabilities for handling real life situations. IS can exploit the tolerance for imprecision, uncertainty/ambiguities, approximate reasoning and partial truth in order to achieve tractability, robustness, and low cost solutions. IS techniques are in general based on biologically inspired strategies for solving problems (Hines et al. 2008). IS techniques include neural networks, fuzzy systems, evolutionary algorithms, genetic programming, support vector machines, particle swarm optimization, memetic algorithms, and ant colony optimization.

### *1.3.1 Particle Swarm Optimization (PSO)*

Particle Swarm Optimization (PSO) is a population based stochastic optimization technique inspired by social behavior of bird flocking. PSO applies the concept of social interaction to problem solving. PSO is a simple but powerful search technique. It has been applied successfully to a wide variety of search and optimization problems.

### *1.3.2 Genetic Algorithms (GA)*

Genetic algorithm (GA) search methods are rooted in the mechanisms of evolution and natural genetics. GAs are part of the adaptive stochastic optimization algorithms involving search and optimization. GAs provide an alternative to traditional optimization techniques by using directed random searches to locate optimal solutions in complex landscapes. Genetic Algorithms are a family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome like data structure and apply recombination operators to these structures so as to preserve critical information.

### *1.3.3 Fuzzy Sets (FS)*

Fuzzy sets are the basic concept supporting the fuzzy set theory. The main research fields in the fuzzy set theory are fuzzy sets, fuzzy logic, and fuzzy measure. Fuzzy reasoning or approximate reasoning is an application of fuzzy logic to knowledge processing. Fuzzy control is an application of fuzzy reasoning to control devices. One feature of FSs is the ability to realize a complex nonlinear input–output relation as a synthesis of multiple simple input–output relations. The fuzzy set theory has been used in several intelligent technologies by today ranging from control, automation technology, robotics, image processing, pattern recognition, medical diagnosis etc. Fuzzy logic and fuzzy set theory have been successfully applied to handle imperfect, vague, and imprecise information. Different generalizations and extensions of fuzzy sets have recently been introduced (Rodriguez et al. 2012): Type-2 fuzzy sets, nonstationary fuzzy sets, intuitionistic fuzzy sets, fuzzy multisets, and hesitant fuzzy sets.

### *1.3.4 Ant Colony Optimization (ACO)*

Ant Colony Optimization (ACO) is a metaheuristic approach for solving hard combinatorial optimization problems. The basic idea of ACO is to imitate the cooperative behavior of ant colonies. When searching for food, ants initially explore the area surrounding their nest in a random manner. As soon as an ant finds a food source, it evaluates it and carries some food back to the nest. During the return trip, the ant deposits a pheromone trail on the ground. The pheromone deposited, the amount of which may depend on the quantity and quality of the food, guides other ants to the food source. Quantity of pheromone on the arc is decreased in time due to evaporating. Each ant decides to a path or way according to the quantity of pheromone which has been leaved by other ants. More pheromone trail consists in short path than long path. Because the ants drop pheromones every time they bring food, shorter paths are more likely to be stronger, hence optimizing the solution.

### 1.3.5 Artificial Bee Colony Optimization (ABCO)

Artificial bee colony (ABC) algorithm is a relatively new member of swarm intelligence. It has received increasing interest because of its simplicity, wide applicability, and outstanding performance. Honey bees use several mechanisms like waggle dance to optimally locate food sources and to search new ones. This makes them a good candidate for developing new intelligent search algorithms. In the ABC algorithm, the colony of artificial bees contains three groups of bees: employed bees, onlookers and scouts. A bee waiting on the dance area for making decision to choose a food source is called an onlooker and a bee going to the food source visited by itself previously is named an employed bee. A bee carrying out random search is called a scout. In the ABC algorithm, first half of the colony consists of employed artificial bees and the second half constitutes the onlookers. For every food source, there is only one employed bee. The employed bee whose food source is exhausted by the employed and onlooker bees becomes a scout (Karaboga and Basturk 2007).

### 1.3.6 Neural Networks (NN)

Neural network (NN) models are inspired by brain processes and structures at almost the lowest level, while symbolic AI models by processes at the highest level. Artificial neural networks (ANN) have been developed as generalizations of mathematical models of biological nervous systems. In other words; ANNs, or simply neural networks, are information processing systems that roughly replicate the behavior of a human brain by emulating the operations and connectivity of biological neurons. ANN models can be used to infer a function from observations. This is particularly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical. ANNs can be trained directly from data. ANNs can be used to extract patterns and detect trends thus it can be applied to data classification and nonlinear functional mapping. Specific application examples include process modeling, control, machine diagnosis, and real-time recognition.

### 1.3.7 Simulated Annealing (SA)

Simulated annealing (SA) methods are methods proposed for the problem of finding, numerically, a point of the global minimum of a function defined on a subset of a k-dimensional Euclidean space. The motivation of the methods lies in the physical process of annealing, in which a solid is heated to a liquid state and, when cooled sufficiently slowly, takes up the configuration with minimal inner energy. SA algorithm is a technique to find a good solution of an optimization problem using a random variation of the current solution. A worse variation is accepted as the new solution with a probability that decreases as the computation proceeds. The slower the cooling schedule, or rate of decrease, the more likely the algorithm is to find an optimal or near-optimal solution (Xinchao 2011).

### *1.3.8 Tabu Search (TS)*

The word tabu (or taboo) comes from Tongan, a language of Polynesia, where it was used by theaborigines of Tonga island to indicate things that cannot be touched because they are sacred. According to Webster's Dictionary, the word now also means "a prohibition imposed by social custom as a protective measure" or of something "banned as constituting a risk." Tabu search (TS) is a higher level heuristic algorithm for solving combinatorial optimization problems. It is an iterative improvement procedure that starts form an initial solution and attempts to determine a better solution.

### *1.3.9 Swarm Intelligence (SI)*

Social insects work without supervision. In fact, their teamwork is largely self-organized, and coordination arises from the different interactions among individuals in the colony. Although these interactions might be primitive, taken together they result in efficient solutions to difficult problems. SI indicates a recent computational and behavioral metaphor for solving distributed problems that originally took its inspiration from the biological examples provided by social insects (ants, termites, bees, wasps) and by swarming, flocking, herding behaviors in vertebrates.

### *1.3.10 Differential Evolution (DE)*

DE is known as population-based optimization algorithm similar to GAs using similar operators; crossover, mutation and selection. DE algorithm uses mutation operation as a search mechanism and selection operation to direct the search toward the prospective regions in the search space. In addition to this, the DE algorithm uses a non-uniform crossover which can take child vector parameters from one parent more often than it does from others. By using the components of the existing population members to construct trial vectors, the recombination (crossover) operator efficiently shuffles information about successful combinations, enabling the search for a better solution space.

### 1.3.11 Evolutionary Algorithms (EA)

Evolutionary algorithms (EA) are search methods that take their inspiration from natural selection and survival of the fittest in the biological world. EAs differ from more traditional optimization techniques in that they involve a search from a "population" of solutions, not from a single point. Each iteration of EA involves a competitive selection that weeds out poor solutions. The solutions with high "fitness" are "recombined" with other solutions by swaping parts of a solution with another. Solutions are also "mutated" by making a small change to a single element of the solution. Recombination and mutation are used to generate new solutions that are biased towards regions of the space for which good solutions have already been seen (Hines et al. 2008).

Intelligent systems have been used in engineering management problems since the end of 1990s. Wang et al. (1998) introduce an intelligent constraint networks management system in concurrent engineering. They present its function frame, and then introduces several main key techniques: visual dynamic simulation, case indexing and retrieval in case-based reasoning system, and hybrid modelling. Prasad (2000) converts computer-integrated manufacturing into an intelligent information system by combining CIM with concurrent engineering and knowledge management. Hu et al. (2002) discuss an intelligent system for the design of demolition blasting, determination of blasting parameters, pretreatment, vibration-control and protection measures and others according to the reasons of accidents occurred in some demolition blasting projects. Johnson (2007) examines "triple helix" collaborations, which are technology development projects that consist of industry, academia, and government partners. He provides engineering managers with a process for engaging in such collaborations. The process offered follows the general stages of a typical project and discusses the challenges that may arise at each stage. The introduction of a fourth party called a "4th Pillar organization" is recommended as a solution to the difficult process of managing triple helix projects. Durakbasa et al. (2012) propose an intelligent design and advanced metrology to support and improve integrated management systems for quality, environment and energy in production engineering. Shao and Fu (2014) propose a framework of intelligent building engineering information management system. Firstly, they illustrate an overview of intelligent building, which include three main parts: (1) Resources, (2) Construction process and (3) Building products. Particularly, the typical services in intelligent buildings construction contain seven types of services, such as Climate controlling, Light control, Safety and security, Traffic condition, Energy consumption control, communication support, and others. Secondly, information processing process of intelligent building engineering information management system is described and framework of the heterogeneous digital system in an intelligent building is proposed. Thirdly, their intelligent building system is organized as the Server/Client structure, and detection module, Engineering information management module, and System maintenance module are included in this system. Mora et al. (2014) propose an intelligent decision-making support systems approach for IT service management and engineering. Trappey et al. (2015) develop an intelligent engineering asset management system for power transformer maintenance. The system performs real-time monitoring of key parameters and uses data mining and fault prediction models to detect transformers' potential failure under various operating conditions. Principal component analysis (PCA) and a back-propagation artificial neural network (BP-ANN) are the algorithms adopted for the prediction model. Historical industrial power transformer data from Taiwan and Australia are used to train and test the failure prediction models and to verify the proposed general methodology as comparative case studies. The PCA algorithm reduces the number of the primary dissolved gasses as the key factor values for BP-ANN prediction modeling inputs. The accuracy rates are much higher when compared to the fault prediction results without using PCA.

## 1.4 Trends for Intelligent Techniques

In this subsection we show the usage frequencies of intelligent techniques in the article titles and give the numbers of articles on engineering and management.

Figure 1.3 shows the usage frequencies of GA with respect to publication years. 11,948 over the total 2,1277 GA articles published between 1981 and 2015 are on engineering while 606 of the total are on business, management, and accounting.

Figure 1.4 shows the usage frequencies of PSO with respect to publication years. 3449 over the total 6048 PSO articles published between 1998 and 2015 are on engineering while 90 of the total are on business, management, and accounting.

Figure 1.5 shows the usage frequencies of fuzzy optimization with respect to publication years. 1198 over the total 1975 fuzzy optimization articles published between 1981 and 2015 are on engineering while 48 of the total are on business, management, and accounting.

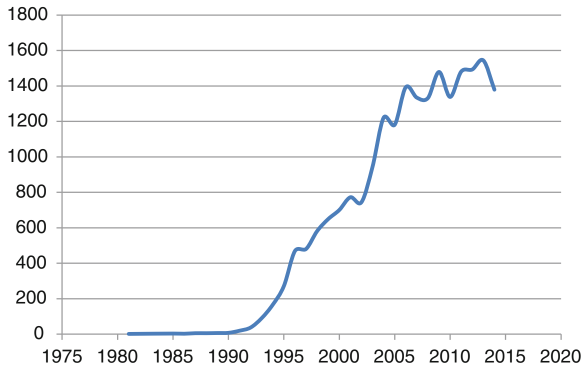


**Fig. 1.3** Usage frequencies of GA with respect to years

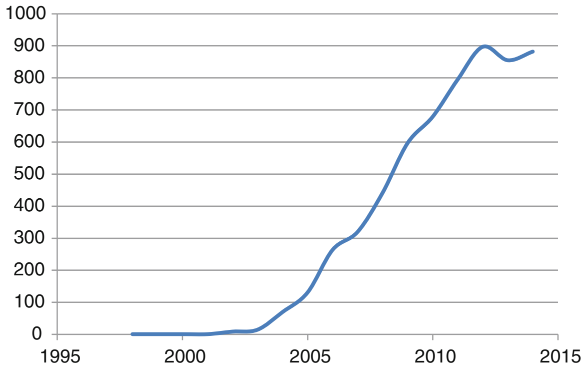


**Fig. 1.4** Usage frequencies of PSO with respect to years

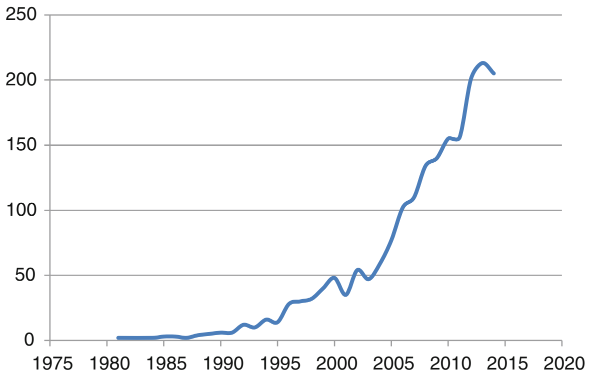


**Fig. 1.5** Usage frequencies of fuzzy optimization with respect to years

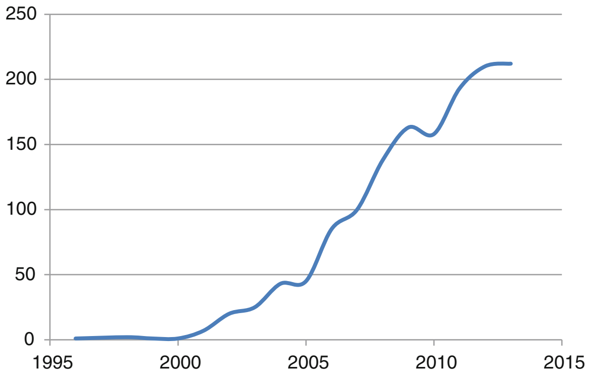


**Fig. 1.6** Usage frequencies of ACO with respect to years

Figure 1.6 shows the usage frequencies of ACO with respect to publication years. 864 over the total 1619 ACO articles published between 1996 and 2015 are on engineering while 59 of the total are on business, management, and accounting.

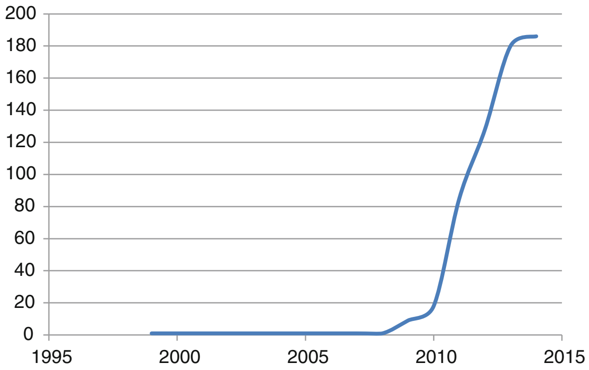


**Fig. 1.7** Usage frequencies of ABC with respect to years

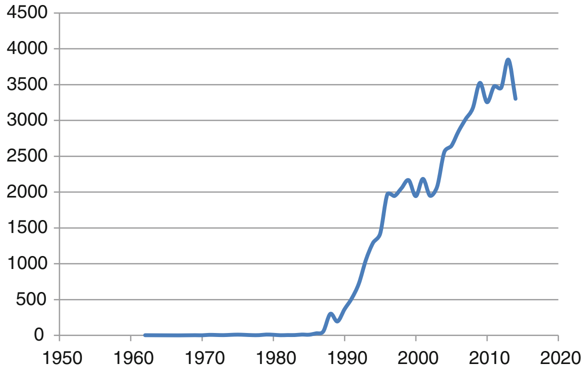


**Fig. 1.8** Usage frequencies of NN with respect to years

Figure 1.7 shows the usage frequencies of ABC with respect to publication years. 329 over the total 633 ABC articles published between 1999 and 2015 are on engineering while 12 of the total are on business, management, and accounting.

Figure 1.8 shows the usage frequencies of NN with respect to publication years. 26,345 over the total 26,345 NN articles published between 1962 and 2015 are on engineering while 956 of the total are on business, management, and accounting.

Figure 1.9 shows the usage frequencies of SA with respect to publication years. 1562 over the total 3440 SA articles published between 1967 and 2015 are on engineering while 104 of the total are on business, management, and accounting.

Figure 1.10 shows the usage frequencies of TS with respect to publication years. 646 over the total 1415 TS articles published between 1987 and 2015 are on engineering while 109 of the total are on business, management, and accounting.

Figure 1.11 shows the usage frequencies of SI with respect to publication years. 178 over the total 406 SI articles published between 2001 and 2015 are on engineering while 9 of the total are on business, management, and accounting.

Figure 1.12 shows the usage frequencies of DE with respect to publication years. 1104 over the total 2454 DE articles published between 1934 and 2015 are on engineering while 33 of the total are on business, management, and accounting.

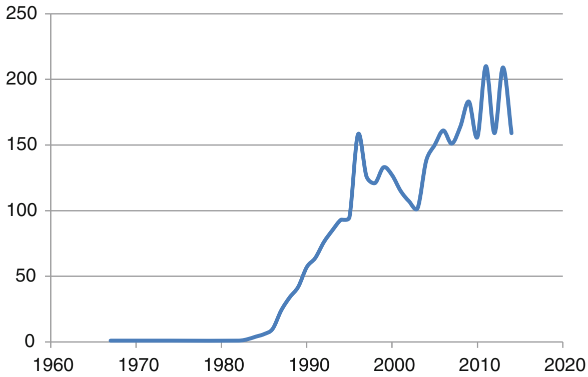


**Fig. 1.9** Usage frequencies of SA with respect to years

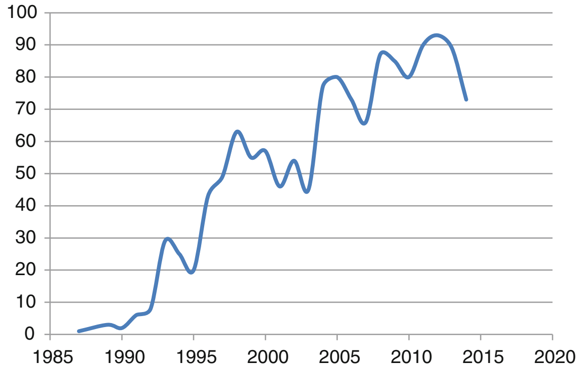


**Fig. 1.10** Usage frequencies of Tabu search with respect to years

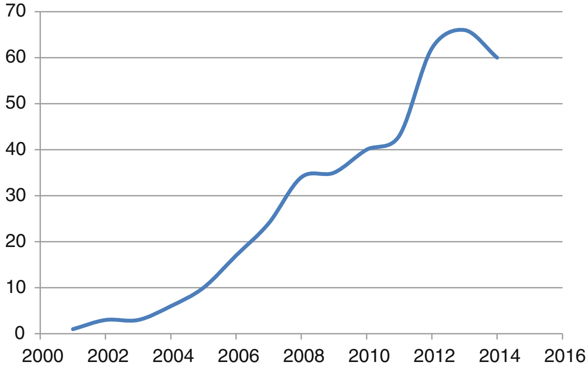


**Fig. 1.11** Usage frequencies of SI with respect to years

Figure 1.13 shows the usage frequencies of EA with respect to publication years. 1616 over the total 3348 EA articles published between 1982 and 2015 are on engineering while 72 of the total are on business, management, and accounting.

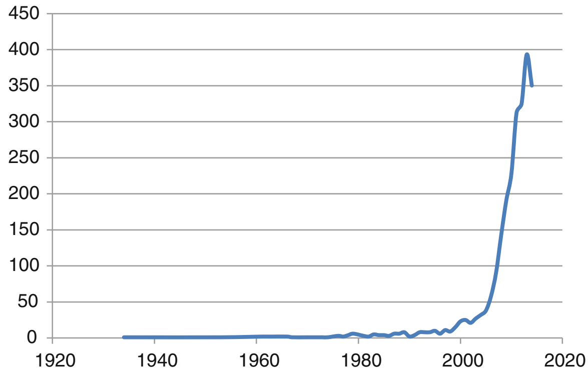


**Fig. 1.12** Usage frequencies of DE with respect to years

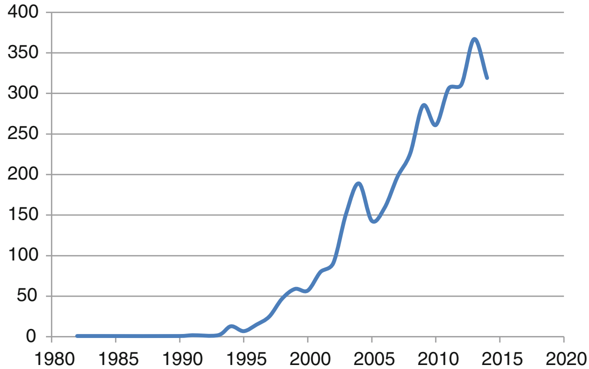


**Fig. 1.13** Usage frequencies of EA with respect to years

## 1.5 Conclusion

Engineering management is a field that concentrates on the application of engineering principles for the effective planning and efficient operations of managing manufacturing or industrial operations. Risk management, customer relationship management, quality management, strategic management, human resources management, marketing and sales management and financial management are all the functions of engineering management field. Intelligent techniques are extensively used in the solutions of engineering management problems since they provide optimum or near to optimum solutions in a reasonable time where the traditional techniques are insufficient for solving these complex problems. Our literature survey showed that the intelligent systems are more and more used for solving complex engineering management problems in recent years. Especially metaheuristics are the tools of intelligent systems used in engineering management.

For further research, we suggest some real application examples of intelligent systems in the various areas of engineering management to be given.

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