ABSTRACT

Fractional calculus is one of the fastest-growing topics in the field of mathematics. There is tremendous growth in applications of fractional calculus in financial management, viscoelasticity, control theory, and special functions. This thesis explores the prospects of fractional calculus on sustainable development goals (SDGs) where no previous studies had attempted.

Diseases such as dengue, malaria, and COVID-19 transmit from an individual to another, and the Fractional order mathematical models of these pandemics produced more accuracy as compared to conventional integer order pandemic transmission model. This is due to the memory property inherited with fractional calculus operators, which consider the history of the considered event. Further, many Fractional order models were proposed, especially in the last decade in the fields like mathematical biology, fluid mechanics, agriculture. Even though various applications of fractional calculus were explored, there is still a vast scope of its applications in sustainable development, specifically in the fields of industrial development with its impact on climate change, sustainable finance, and sociology. With the objective of contributing to the sustainable future, this study intends to explore the prospects of applying fractional calculus for sustainable development growth. Since there are multiple dimensions associated with SDGs, a short review is conducted at the primordium of this study to identify the crucial domains which need more emphasis in the current scenario. A few of the goals which can trigger the other are identified, and due importance is given in this work. "Innovation Industries and Infrastructure," "Decent work and economic growth," and "Justice and Strong Institutions" are the three different goals chosen for this doctoral work.

A wide range of scientific publications, documents, and mathematical models are reviewed and discussed in the thesis. An introduction to fractional calculus along with sustainable development goals, are presented in Chapter1. Further, the fundamentals of advanced mathematical tools such as fuzzy logic and particle swarm optimization are also given in Chapter 1. These tools, along with fractional calculus, help to achieve sustainable development goals.

One of the vital applications of fractional calculus in the past decade is in the field of control theory. In control theory, the overshoot, rise time, and the settling time of a power system can be

optimized by using a PID controller. Overshoot, rise time, and the settling time of a power system can be further minimized by using a fractional order controller named fractional order PID controller. In Chapter 2, the dimensional aspect of the fractional PID controller is discussed and found to be dimensionally inconsistent with respect to the conventional PID controller. Further, a robust fractional order PID controller named dimensionally balanced fractional order PID controller is proposed in the chapter, which not only addresses the dimensional aspect but also yields better values of overshoot, rise time, and the settling time of a power system. The introduced fractional order controller will help to achieve sustainable development goals such as Industry, Innovation and Infrastructure, and Climate Change.

Another sustainable development goal, "Decent Work and Economic Growth," is of great importance for sustainable growth and is highly correlated with other goals such as no poverty and zero hunger. This is especially useful to achieve good results in developing and fast-growing economies like India and China. In this goal, one of the targets to be performed by the year 2030 is to provide an enhanced framework for financial planning for well being of the society. Chapter 3 and Chapter 4 provide an advanced yet widely applicable strategy for the portfolio management of novice investors.

The introduced strategies not only applicable in financial portfolio management but can be further utilized in the fields of network structures, supply chain management, research institutes feasibility, and large-scale rooftop photovoltaic. A case study is presented by explicitly analyzes six sectors in BSE SENSEX using two fuzzy Multi-criteria decision-making techniques (MCDM) Fuzzy AHP and Fuzzy TOPSIS to find increasing dominance of each sector. Various parameters that help to measure the performance of the sector/market are presented in Chapter 3.

Based on the cumulative scores obtained in Chapter 3, three portfolios depending on the perception of an investor using an advanced clustering algorithm known as the Fractional Lion Algorithm, are constructed in Chapter 4.

Even though there are many applications of fractional calculus in the fields of control theory and finance, there are limited applications in criminology, which is the field of social science. Hence

a Fractional order crime transmission model is proposed in Chapter 5 of the thesis. The equilibria of the proposed three-dimensional fractional crime transmission model are evaluated using phase-plane analysis, and the Lyapunov function is employed to determine stability and threshold conditions to achieve a crime-free society. This model will help to attain sustainable development goal of "Peace, Justice, and Strong Institutions."

A summary and conclusions are provided in the final chapter of the thesis, i.e., Chapter 6, based on the results and objectives of the study. The future scope is also given in this chapter. Overall, this thesis explores and discusses various prospects of applying fractional calculus to achieve sustainable development goals. Further, the application of fractional calculus in criminology, which is not discussed in any of the past works, provides excellent scope for future studies.

Keywords: Fractional calculus, Sustainable development goals, Dimensionally balanced PID controllers, Fuzzification, Cumulative Score, Defuzzification, Portfolio management, P-index, Multi-criterial volatility, Fractional clustering algorithm, Stock market Index, Perception-based optimization Fractional order crime transmission mathematical model, Equilibrium points, Stability, Phase-plane analysis, Lyapunov function.