The aim of this research work is to design and develop a multi-agent decision-making system to allocate funds to the deserving fund seekers both individual and organizations for executing their projects and to monitor the progress of the projects. Funds are considered as main resource required to execute the project apart from other resources like workforce and infrastructure. The system considers quantitative and non-quantitative decision-making factors while allocating funds. Quantitative factors are easy to measure like the number of students to be trained while non-quantitative factors are subjective in nature like impact of project on the society and image of the fund seeker. Monitoring is an integral part of the funding and helps in knowing the fulfillment of the objectives for which funds are given. In this process, two types of agencies are involved: fund seeker and fund allocator. Fund seeker submits proposals to avail funds and the fund allocator allocates the funds. Fund allocator also monitors the progress of the projects. This decision-making problem of resource allocation and monitoring is solved using software agents. Software Agent is an autonomous entity capable of performing the task independently after gathering information from environment. Systems having group of agents working in single environment to achieve common goal is called Multi-agent System (MAS). The more details on resource allocation & monitoring system, MAS, Problem Statement and Research Contribution are given in Chapter 1.

Conceptual review of the related literature shows that fund proposals are scrutinized, evaluated and ranked. Based on rank of proposals, funds are allocated using different techniques like incremental, negotiation and weight-based. In incremental approach, allocator starts with initial allocation and continues allocating funds to all till the funds are exhausted. In negotiation, first funds are allocated to all the proposals and then funds are moved from one location to the other depending upon objectivity of the proposal. In weight-based approach, weights are given to the proposals depending upon their importance and funds are given according to weights. From the technological review of literature, it is observed that funding agencies are using tools like Excel Solver to automate the procedures. Multi-agent systems are used to allocate other resources like network connection and processor timings.
Based on the conceptual and technological reviews, a research work to design and develop a Multi-agent System for Resource Allocation and Monitoring (MASRAM) is carried out. Chapter 2 discusses the detailed conceptual & technological reviews of literature and research methodology adopted to complete the research.

The system is modeled using multi-agent Technology. The model includes procedures for fund seeking, procedures for fund allocating, three software agents and four system users who interact with the system. Fund seeking procedures comprise finding sources for funding agencies and submission of proposals. Fund allocating procedures include proposals, evaluation of proposals, fund allocation and monitoring the progress. Three agents are Fund Seeker Agent (FSA), Fund Allocator and Monitor Agent (FAMA) and Facilitator Agent (FCA). FSA helps the fund seeker in submitting the proposal and progress of the project by providing interfaces. FAMA helps fund allocator in allocating funds and monitoring the progress. Four identified system users are fund seeker, fund allocator, expert and reviewer. These users interact with agents of the system with the help of FCA. FSA takes input on the proposal from the fund seeker and forwards it to FAMA for fund allocation. It is also responsible to capture data on the progress of the project and forwarding to FAMA. FAMA helps the fund allocator in allocating funds, reviewing allocation and monitoring the progress. FCA acts as a mediator between agents (FSA and FAMA) and users. The roles and responsibilities of identified agents and users along with procedures are described in detail in Chapter 3.

The agents interact with each other to complete the task as the required information/knowledge and rules are distributed among them. For example, FAMA interacts with FSA to get proposal data. This communication takes place between agents using Ontology with back support of database. Ontology is designed to represent knowledge that is shared between agents of MASRAM. Database and actions performed by the three agents are also designed in detail. One of the major actions performed by FAMA is the procedure to allocate funds. In this direction, a weight-based distributed algorithm is designed and implemented. The algorithm compares proposals relatively, for example proposal P1 is 2 times better than proposal P2. The algorithm includes following steps.

1. Information Gathering: In this step, FSA gathers information regarding proposal from fund seeker and submits the same to FAMA. FAMA captures
other required information like availability of funds, experts’ feedback on presentation and criteria to qualify for funding.

2. Filtering Proposals: Once FSA submits the proposal, FAMA extracts information from the proposal as per minimum eligibility criteria and matches with the qualifying criteria set by the fund allocator. The proposals satisfying minimum criteria are made eligible to avail the funds. Remaining proposals are rejected.

3. Reviewing Proposals: Sometimes the fund seekers are required to present their proposals before the experts. The experts provide feedback. Each expert is provided a checklist where he/she has to give answer in ‘Yes’ or ‘No’. FAMA, after getting the feedback from the experts, compiles the feedback and assigns a numeric value. The proposals getting the minimum qualifying scale are considered for funding; remaining proposals are denied funds.

4. Evaluating Proposals: After the literature survey and interaction with experts, twelve decision-making factors, classified into five categories are identified and used in fund allocation. The five broad categories are solution delivery & contribution, technical, financial, capacity & expertise and risk analysis. These factors are further divided into sub-factors e.g. risk analysis has two sub-factors: project completion risk and implementation risk. To evaluate decision-making factors, keywords provided by the fund allocators for non-quantifiable factors are searched in the proposals. After finding keywords, AHP (Analytic Hierarchy Process) technique is applied to compare the proposals. AHP is used to compare the alternatives using pairwise comparison matrix. It gives relative scale to proposals.

5. Allocating Funds: The relative values calculated during evaluation are given weightage according to the weights provided by the experts of this area. A well-defined questionnaire consisting of twelve decision-making factors was given to the experts. These experts were requested to give their preferences. After giving weights, the values are evaluated to get a single numeric value corresponding to each proposal. FAMA ranks the proposals. Proposals are then allocated funds depending upon the availability of the funds and policy set by the fund allocator.
Allocation is done from zero to 100 percent. If the weighted relative scale (numeric value calculated) of a proposal falls below the minimum requirement, proposal is rejected. The ontology, database and detailed actions performed by agents are given in Chapter 4.

The agents of MASRAM are implemented using three-layered architecture in web-based environment: Presentation Layer, Agent Layer and Database Layer. FCA uses presentation layer to interact with users while FSA and FAMA use database layer to interact with database. The actions of these agents are implemented in the agent layer.

1. **Presentation Layer**: Presentation layer includes user-friendly interfaces developed using JSP (Java Server Pages). Interfaces for searching funding agencies, proposal submission, viewing the status etc. are provided to the users. FCA provides these interfaces to the users of the system.

2. **Agent Layer**: Actions of agents are implemented in this layer using Java Agent Development Framework (JADE). The business logic is implemented using Java packages as classes and the instances of these classes are created as objects to invoke methods to perform actions. These classes interact with the database using JDBC (Java Database Connectivity).

3. **Database Layer**: Agents store data like proposals, funds available and criteria to qualify for funding in database. FSA stores proposals and FAMA picks proposals to allocate funds. Oracle 9i database is used to store data. Data is stored as database objects like tables, views and procedures.

The developed agents are platform independent. Agents are deployed in Windows platform to verify the implemented system. Agent Server is used to deploy Agent Layer and Presentation Layer. Database Layer is deployed at Database Server. Users access the system through web-browser. The implementation details are provided in Chapter 5.

The system is verified against generated test data for both organizational and individual fund seekers. The generated test proposals and progress reports related with the projects are also entered. The allocation done by FAMA is verified. The results of verification confirm that the desired objective to allocate funds and monitor the progress has been achieved. The details of verifications and result are included in Chapter 6.
The thesis presents the methodology adopted to design and develop Multi-agent System for Resource Allocation and Monitoring, its implementation and tests carried out to verify the solution. This system helps in bringing more transparency, applying uniform allocation policy, monitoring the timely utilization of funds and getting the status with regard to the fulfillment of objectives for which funds are given.