Mathematical modeling for the location-allocation problem - allocation of mobile operator subscribers' affairs' agencies under uncertainty conditions

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Abstract— **Mobile phone is one of the inventions of the twentieth century that no one could have imagined that it will grow and become a profitable and huge industry in the world. Therefore, the importance of mobile operators and their services is not recondite. In fact, mobile operators provide access to telecommunications services for users and in return receive a commission. In this study, the locations of mobile operator subscribers' affairs' agencies in Tehran are investigated using robust optimization approach and scenario building. Uncertain parameters considered in this study include radius of coverage of demand for subscribers' affairs' agencies, demand of each region, and cost of establishing subscribers' affairs' agencies.**

Keywords— location; allocation; uncertainty; robust optimizatio; Mulvey approach

I. INTRODUCTION

For different operators, customer service centers or subscribers' affairs' agencies are very important in attracting and keeping customers. The goal of establishing these agencies is to provide all services to customers and address their complaints.

Establishing subscribers' affairs' agencies is a strategic and somewhat costly decision. The location of establishing these agencies should be chosen properly so that construction and operation costs are justifiable. On the other hand, according to forecasts of an increase in demand for enjoyment, considering appropriate infrastructures to meet the demand of customers is of great importance and lack of attention to this matter can definitely interfere in the development of operators' profitability. Therefore, it is necessary to pay due attention in choosing the location of establishing subscribers' affairs agencies so that the location is chosen according to criteria and standards that ensure the achievement of goals.

Literature review

S.Zokaee & etal.[1], suggested a three-level relief chain model consisting of suppliers, relief distribution centers, and affected areas is considered. . The uncertainty associated with demand, supply, and all of the cost parameters is addressed by employing robust optimization, where the uncertain parameters are independent and bounded random variables. A data set derived from a real disaster case study in the Alborz area, which is vulnerable to earthquakes, is applied to test the efficiency of the proposed robust relief chain model compared to its deterministic form. The study analyzes the degree to which each uncertain parameter affects the solution of the relief chain model and consequently helps the decision maker to tune the parameter values more accurately.

Abbasi & Taghipour,[2],The present study tries to focus on the problem of finding the maximum flow along with the shortest path in adynamic network that this type of the network is presented in. For solving bi-criteria network problems, a two-phased exact algorithm and an ant colony (ACO) algorithm based on bi-criteria are used, where the two-phased exact algorithm is presented by Abbsi et al. and the bi-criteria ant colony algorithm ispresented by Ghoseiri et al.. The computational results for 33random instances showed that, the CPU time of the ACO algorithm has exponential growth comparing to the two-phased complete enumeration algorithm.

E. Bakhtavar & H. Mahmoudi, [3] develop a scenario-based robust optimization (SBRO) approach to solve truck–shovel allocation (TSA) problem.And also compared the results of the SBRO approach with the current TSA of the studied mine. Then, we update the TSA formulation based on two new strategies of increasing shovel number and shovel capacity. Compared to the traditional strategy of the mine, the output of shovels increases to 6719, 10000, and 12500 tons/shift by the SBRO approach based on the strategies of the available equipment, increasing the

number of shovels, and increasing the capacity of shovels, respectively.

Taghipour et al. [4], studied Risk analysis in the management of urban construction projects from the perspective of the employer and the contractor.Imbalance between anticipated and actual progress in the development of urban construction projects suggests that there are many obstacles and risks which not only causes the urban management be unsustainable, but the reconstruction and development of urban space is also seriously threatened. the results indicated that the experts listed the most significant risks as the delays in the payment of contractors' claims and statements due to the lack of handling financial instruments, the governance of relationships rather than rules in the tenders resulting from employer actions, low commitment to the quality of work provided by their subcontractors, failure to complete the detail engineering by foreign contractors on time, weaknesses in contractors' financial resources, and offering lower prices than reasonable by contractors to win the tender. Finally, the solutions for eliminating or reducing risks in high risk areas have been offered to provide tranquility for contractors and employers.

Rezvani Befrouei MA et al.[5], discussed Identification and Management of Risks in Construction Projects. Today, risk management in construction projects is considered to be a very important managerial process for achievement of project's objectives in terms of time, costs, quality, safety, and environmental sustainability. Instead of employing a systematic approach for identification of risks, their probability and their effects, most of the studies conducted inthis area have focused only on a few aspects of risk management in construction project. the present study aims to identify and analyze the risks associated with development of construction in the greater city of Tehran, employing a comprehensive approach that is consisted of five aspects. After the collection and observation of the data, the output was examined by Pearson correlation also, using charts and tables. The results indicated that "tight project schedule" present in all five categories- imposed the maximum risk. Also "design variations", "excessive approval procedures in administrative government departments" and "unsuitable construction program planning" were identified as next high risk factors.

Taghipour et al.[6], studied Analysing the Effects of Phisical Conditions of the Workplace on Employees Productivity. One of the issues that today will improve the productivity of any organization is attention to the human factors engineering. The aim of this study was to find the amount of employee's satisfaction from environmental and organizational factors of their jobs, thus providing guidelines for improving the identified problems which eventually will lead to increase the productivity.

Baghipour sarami et al.[7], studied Modeling of Nurses' shift Work schedules According to Ergonomics: A case study in Imam sajjad (As) Hospital of Ramsar. In this study, 35nurses working in the emergency ward of Imam Sajjad (AS) Hospital of Ramsar city, Iran, were considered. The final model was implemented with GAMS and at the end, shift working with ergonomic criteria were proposed .The results showed that the proposed working program on one hand will improve satisfaction and efficiency of nurses and on the other hand it can decrease the effects of disorders on shift work.

Taghipour et al.[8], studied Supply Chain Performance Evaluation in IN The IT Industry. The appraisal of several performance measure agendas and metrics already accessible proposes that supply chain performance measure can be detected under different categories such as cost and non-cost. In this study, developed supply chain of IT industry based on BSC from existing decision making models. Then, industrial projects performance and performance evaluation measures have been determined using a designed questionnaire.

Taghipour et al.[9], studied A Survey of BPL Technology and Feasibility of Its Application in Iran (Gilan Province).Recently Broadband over power lines (BPL) has received much attention in communication technology and this is due to economically of sending high data rate services by re-use of power line cables. As data transfer via power lines to final consumer is one of the growing technologies, this study discusses the modeling and optimization of data transfer via power transfer lines and feasibility and adaptation of using this technology in Gilan are investigated.

Khalilpour et al. [10], While explaining the concept of social responsibility, based on the conceptual framework of accounting and the reporting framework of common social responsibilities, examined the desired features and sought to provide a conceptual framework for reporting corporate social responsibility. The research results show that there are many similarities with the field of financial reporting in terms of reporting objectives, qualitative characteristics of information, responsibility for preparing and presenting reports, accreditation, institutions that formulate corporate social responsibility standards and financing.

Taghipour et al.[11], studied the Study of the Application of Risk Management in the operation and Maintenance of Power Plant Projects. one of the methods used in good decision making, pay attention to risk management, which is known as an important part of project management and control. Risk management has evolved over time and its systematic method has provided managers with a definite path so that they reduce potential threats to a minimum and reach project goals by the least possible deviations. In this paper, subsequent to an introduction of fundamental concepts of risk, risk management, an account of risk management, methods and its techniques are presented. In the end, following a discussion on how it is practically used in projects in a real and practical sample, risk management and its

application are implemented and essential investigations are undertaken into its effects.

Taghipour et al.[12], studied Identification and Modeling of Radio Wave Propagation Channel in Industrial Environments.Wireless technology in industrial environments is considered due to potential for saving in cable cost, high flexibility in factories, tracing the products and increasing optimization of process.

Mahboobi et al.[13], discussed Assessing Ergonomic Risk Factors Using Combined Data Envelopment Analysis and Conventional Methods for an Auto Parts Manufacturer. occupational injuries are currently a major contributor to job loss around the world. They are also costly for business. The absence of rational analysis is felt in this area, so mathematical analysis is needed to obtain the logical results of these injuries in order to find gaps or loss points of industry. OBJECTIVE: This paper assesses the effect of five demographic factors on ergonomic risk and occupational injuries using an integrated mathematical programming approach. The obtained results will help managers to carry out any required corrective actions or establish benchmarks.

Taghipour et al.[14], studied Assessment and Analysis of Risk Associated with the Implementation of Enterprise Resource Planning (ERP) Project Using FMEA Technique. Enterprise resource planning (ERP) is one of the latest management tools that can take advantage of information technology to comprehensively gather resources and information in all parts of the organization by an interlocking, system with fast speed and high quality and help users in all organizations and sectors by giving certain modules for managing different sectors such as projects, human resources, and services. Despite the many benefits this system can have for the organization, its implementation and deployment is very risky and costly.

Taghipour et al.[15], studied Construction projects risk management by risk allocation approach using PMBOK standard. Projects' managers in plenty of construction projects which are assumed that are under control, are facing risk as an unknown occurrences and they are attempting to control it and are suffering more costs. Though, by a comprehensible effort and applying risk management, risks are identified and controlled before happening or a plan is provided in order to deal with these occurrences and time and cost are saved. Thus, they have to be controlled and appropriately responded by risk management methods. In this regard, risk management process in PMBOK standard can be a suitable approach to solve this problem.

Taghipour et al.[16], studied The Evaluation of the Relationship between Occupational Accidents and Usage of Personal Protective Equipment in an Auto Making Unit. One of the problems that encounter each work society is occupational accidents. Today, despite the improvements of facilities and working conditions, the possibility of accident occurrence in workplaces and especially in industrial places is inevitable. Since the non-use or misuse of PPE is one of the main causes of accidents in industrial units, the aim of this study is to evaluate the association between occupational accidents and the use of PPE in the body section of a vehicle manufacturing unit. The results showed that there is a meaningful positive relationship between the factor of inadequate PPE and probable hazards of the industrial workplace.

Taghipour et al.[17], studied Necessity Analysis and Optimization of Implementing Projects with The Integration Approach of Risk Management and Value Engineering. Risk management and value engineering have appeared as modern management tools since the mid-19th century and have been used separately in different projects. Due to the ineffectiveness resulting from separate implementation of the two approaches in major projects as well as the similarity between them in terms of their goals and executive structures, this research tries to analyze the separate role of each approach in the project process and examine the possibility of integration and correlation between their different phases. This article aims at introducing and examining a tool that simultaneously has the capability of the two categories.

Taghipour et al.[18], studied Evaluating Project Planning and Control System in Multi-project Organizations under Fuzzy Data Approach Considering Resource Constraints. Projects can be repetitive tasks in specified periods of time and also it may involve some functions which are performed just once. However, in any project, managers and experts consider three basic and important goals: least time, lowest cost and best quality, so all efforts are directed toward achieving these basic goals. Statistics indicate that projects are either conducted on estimated time or delayed and rarely are delivered before due date.

Taghipour et al.[19], studied Implementation of Software-Efficient DES Algorithm. By increasing development of digital telecommunication and the increase of sending and receiving data of various network of data transfer, protection of the safety of data are the most important necessities of the current world. The increase of different bank trading, increasing use of smart cards, moving to electronic government, are the examples of significance of this issue. In this study, an efficient algorithm implementation by MATLAB and C language is presented and is compared with the latest works in this field.

Sedaghatmanesh and Taghipour [20], studied Reduction of Losses and Capacity Release of Distribution System by Distributed Production Systems of Combined Heat and Power by Graph Methods. Formulation of long term program of optimization of energy sector has positive effect on economy of country and improving the role of Iran in global energy markets. One of the results of optimization of energy supply sector is improvement of efficiency and

reduction of environmental pollutants of energy generation.

Taghipour et al.[21], studied Risk assessment and analysis of the state DAM construction projects using FMEA technique. Dam construction projects are the most important projects of the country and absorb a considerable amount of the state budget on annual basis. As they take a long time to be completed, they always face risks and many uncertainties. In this study, the researcher intends to use a highly applied qualitative-quantitative methodology (FMEA) to analyze the risks of state dam.

Taghipour et al.[22], studied the impact of ICT on knowledge sharing obstacles in knowledge management process.Today, knowledge is known as a valuable asset in any organization so management of such insensible asset is one of the factors cause success in organizations. But knowledge can be effective when it is shared across the organization. Therefore, knowledge sharing is a key element in the process of knowledge management. This study aimed to check the impact of ICT on knowledge sharing barriers in one of the mobile operator, in Tehran.

Taghipour et al.[23], studied Assessment of the Relationship Between Knowledge Managment Implementation and Managers Skills. The Purpose of this study is to consider the effects of knowledge management implementation on manager's skills of Reezmouj System Company. Results showed that there is a relation between knowledge management.

Taghipour et al.[24], studied Evaluation of the effective variables of the value engineering in services. The value engineering is a systematic method for resolving the problems, reducing the cost and improving the function and quality simultaneously and this leads to the increase of customer satisfaction by investigating and improving the value index. The results of this research which are based on the post managers and specialists responses show that applying value engineering by the post managers has significant effects on reducing the cost, saving time and customer satisfaction.

Taghipour et al.[25], studied Evaluating CCPM method versus CPM in multiple petrochemical projects. Although project management has long been under consideration and various methods have been proposed for timing projects, but they have not been completely responsive to the needs of the project for increasing productivity and customer satisfaction. As a result, increased risks and the incompatibility of the project with the initial Base line plan, necessitate using modern techniques (such as CCPM) as opposed to common methods (such as CPM).

Bairamzadeh & etai [26], proposes a mixed-integer programming (MILP) model to determine the strategic and 8 tactical level decisions of lignocellulosic bioethanol supply chain subject to different sources and types of uncertainty. Computational results show that the proposed robust model outperforms

deterministic model in terms of given performance measures.

$$Min \sum_{i=1}^{20} C_i X_i$$

$$s.t. \sum_{i=1}^{20} A_{ij} X_i \geq 1, \quad j = 1,...,41$$

$$X_i \in \{0,1\}$$

II. RESEARCH HYPOTHESES

In the study, several hypotheses are developed as follows:

• Demand in Tehran is considered discretely and 41 demand point with same distances are considered across Tehran.

• Coverage radius is considered to be 7 km.

• There are 20 candidate points to establish subscribers' affairs' agencies.

III. DECISION MAKING UNDER UNCERTAINTY CONDITIONS

In mathematical programming, it is assumed that the input data are precisely known and the effect of data uncertainty on optimality and justifiability of the model is ignored. Therefore, it seems that as soon as the data take values other than their nominal value, several restrictions may be violated and optimum answer obtained for nominal values may not be optimal or even justified anymore. When the data of the objective function are uncertain, the optimality of the obtained answer is in jeopardy by changing the nominal values and when the data relating to restrictions are not certain, the justifiability of the obtained answer is concerned. Observation of this natural question in the design of approaches to find optimal solutions secured against data uncertainty leads to the fact that these answers are called "robust".

IV. ROBUST OPTIMIZATION

The process of finding suitable variables for design is usually called optimization. The optimum value changes due to changes in the input values. Generally, there are two general practices in modeling optimization problems under uncertainty using robust optimization. The first time, Mulvey et al [27] proposed a model for robust optimization using the sum of weighted means and variance of objective function, which is a combination of goal programming formulation and expression of base option of variables. The second method is to find the worst answer for optimization problem, while maintaining the level of uncertainty entered in it. The first time, Soyster [28] proposed linear optimization model to find possible answers for all data under uncertainty conditions,

which only optimizes the objective function for the worst uncertainty conditions [28].

V. MODELING AND NUMERICAL RESULTS OF THE MODEL

A. Set covering model

The desired locations for the construction of subscribers' affairs' agencies are determined using set covering model and with the goal of minimizing construction costs. A number of locations with the lowest possible construction cost is selected so that all demand points are covered.

(1)

B. Two-objective allocation model

To allocate any of the demand points to the selected points, two-objective allocation model is used.

Two-objective allocation model is as follows:

$$Min\ B$$

$$Min \sum_{j=1}^{41} t_{1j}w_j y_{1j} + \sum_{j=1}^{41} t_{2j}w_j y_{2j} + \sum_{j=1}^{41} t_{6j}w_j y_{6j} + \sum_{j=1}^{41} t_{10j}w_j y_{10j} \quad (2)$$

$$+ \sum_{j=1}^{41} t_{11j}w_j y_{11j} + \sum_{j=1}^{41} t_{12j}w_j y_{12j} + \sum_{j=1}^{41} t_{16j}w_j y_{16j} + \sum_{j=1}^{41} t_{19j}w_j y_{19j}$$

$$s.t. \sum_{j=1}^{n} w_j y_{kj} \le B \quad \forall k = 1,2,6,10,11,12,16,19$$

$$y_{kj} \le a_{kj}$$

$$\sum_{k=1}^{q} y_{kj} = 1 \quad \forall j = 1,...,40$$

$$y_{kj} \in \{0,1\}$$

C. Robust set covering model

In the set covering model, the cost of construction and coverage radius are uncertain. Of these parameters, construction cost is capable of making the problem non-optimal and covering radius is capable of making it unjustifiable. Thus, taking into account the uncertainty of these two parameters, robust set covering model is defined as follows.

$$\min z = \sum_s p^s (\sum_{i=1}^{20} c_i^s x_i) + \lambda_2 \sum_s p^s \left[\sum_{i=1}^{20} c_i^s x_i - \sum_{s'} p^{s'}(\sum c_i^{s'} x_i + 2\theta^s) \right] + \omega_1 \sum_{s,i,j} p^s \delta_{1ij}^s$$

$$s.t. (\sum_{i=1}^{20} c_i^s x_i) - \sum_s p^s (\sum_{i=1}^{20} c_i^s x_i) + \theta^s \ge 0 \quad j = 1,...,41 \quad (2)$$

$$\sum_{i=1}^{20} A_{ij}^s x_i + \delta_{1ij}^s \ge 1$$

$$x_i \in \{0,1\}$$

$$\theta^s, \delta_{1ij}^s \ge 0 \quad \forall s,i,j$$

D. Solving robust set covering model

The coefficients of the Mulvey method for the problem under study are as follows.

$$\omega_1 = 23$$

$$\lambda_2 = 0.5 \quad (3)$$

The following values are the final answer of the robust set covering problem.

$$X_1 = X_6 = X_7 = X_{10} = X_{11} = X_{12} = X_{17} = X_{18} = X_{19} = X_{20} = 1 \quad (4)$$

E. The robust two-objective allocation model

Taking into account the uncertainty of data, the robust allocation model is presented to allocate demand points to selected points.

$$Min_{z_1}\ B$$

$$Min_{z_2} = \sum_s p^s (\sum_{j=1}^{41} t_{kj} w_j^s y_{kj})$$

$$+ \lambda_3 \sum_s p^s \left[\sum_{j=1}^{41} t_{kj} w_j^s y_{kj} - \sum_{s'} p^{s'}(\sum_{j=1}^{41} t_{kj} w_j^{s'} y_{kj}) + 2\theta^s \right]$$

$$+ \omega_1 \sum_{s,j} p^s \delta_{1kj}^s + \omega_3 \sum_{s,j} p^s \delta_{3j}^s \quad k = 1,6,7,10,11,12,17,18,19,20$$

$$S.t.$$

$$(\sum_{j=1}^{41} t_{kj} w_j^s y_{kj}) - \sum_s p^s (\sum_{j=1}^{41} t_{kj} w_j^s y_{kj}) + \theta^s \ge 0 \quad (5)$$

$$y_{kj} \le a_{kj}^s + \delta_{1kj}^s \quad k = 1,6,7,10,11,12,17,18,19,20$$

$$\sum_{j=1}^{n} w_j^s y_{kj} - \delta_{3j}^s \le B \quad k = 1,6,7,10,11,12,17,18,19,20$$

$$\sum_{k=1}^{q} y_{kj} = 1 \quad \forall j = 1,...,41 \quad k = 1,6,7,10,11,12,17,18,19,20$$

$$y_{kj} \in \{0,1\}$$

$$\delta_{1j}^s, \delta_{3j}^s \ge 0$$

$$\theta^s \ge 0$$

F. Solving the robust two-objective allocation model

The coefficients of robust two-objective allocation problem are as follows:

$$\omega_1 = 11$$

$$\omega_3 = 31$$

$$\lambda_3 = 0.5$$

The solution of robust set covering and allocation problems is presented in the following table.

TABLE 1: THE SOLUTION OF ROBUST LOCATION AND ALLOCATION PROBLEMS

Selected point (decision variable)	Allocated demand points
(X_1)	$(j_2) \cdot (j_5)$
(X_6)	$(j_8) \cdot (j_{11}) \cdot (j_{12})$
(X_7)	$(j_{18}) \cdot (j_{22}) \cdot (j_{23}) \cdot (j_{31}) \cdot (j_{32}) \cdot (j_3)$
(X_{10})	$(j_{24}) \cdot (j_{25}) \cdot (j_{28}) \cdot (j_{35}) \cdot (j_{36})$
(X_{11})	$(j_3) \cdot (j_4) \cdot (j_6) \cdot (j_7) \cdot (j_{17})$
(X_{12})	$(j_1) \cdot (j_9) \cdot (j_{10}) \cdot (j_{13}) \cdot (j_{20}) \cdot (j_{21})$
(X_{17})	$(j_{34}) \cdot (j_{38}) \cdot (j_{39})$
(X_{18})	$(j_{14}) \cdot (j_{15}) \cdot (j_{16}) \cdot (j_{19})$
(X_{19})	$(j_{29}) \cdot (j_{30}) \cdot (j_{40}) \cdot (j_{41})$
(X_{20})	$(j_{26}) \cdot (j_{27}) \cdot (j_{37})$

VI. VALIDATION OF THE MODEL

To validate the model that has been solved in the previous step, the certain problem and certain solutions are first taken into account. The third scenario is the certain values that certain models were solved using them.

The three parameters of coverage radius, construction cost, and demand are changed for this certain solution and the response status is examined in terms of its feasibility.

TABLE 2: JUSTIFIABILITY STATUS OF THE CERTAIN PROBLEM UNDER SEVERAL SCENARIOS

R	Coverage radius	Construction cost	Demand	Justifiability status
1	Scenario 1	Scenario 5	Scenario 5	Unjustified
2	Scenario 2	Scenario 5	Scenario 5	Unjustified
3	Scenario 2	Scenario 5	Scenario 4	Unjustified
4	Scenario 1	Scenario 5	Scenario 4	Unjustified
5	Scenario 1	Scenario 4	Scenario 5	Unjustified

The conclusion that can be drawn from this part is that in accordance with the expectation of a problem with uncertain data in nature, but certain data in the solution, responses were practically invalid.

VII. SENSITIVITY ANALYSIS

The same weight (.5) is given to each objective in solving the two-objective allocation problem. Now, to ensure the solutions and achieve management objectives, different weight are given to each of the goals and the results are examined. In addition to equal weights, the following modes are evaluated:

TABLE 3: SENSITIVITY ANALYSIS OF OBJECTIVE FUNCTIONS' WEIGHTS IN ALLOCATION PROBLEM

R	The weight of the objective of balancing demand	The weight of the objective of minimizing the distance travelled
1	0.1	0.9
2	0.2	0.8
3	0.3	0.7
4	0.4	0.6
5	0.6	0.4
6	0.7	0.3
7	0.8	0.2
9	0.9	0.1

It can be concluded that the solution meets the condition in which the decision-maker prioritizes each objective based on the current situation.

VIII. CONCLUSION

Robust Optimization approach was used for the consideration of uncertainty in parameters and uncertain data of the problem. The uncertain parameters are as follows:

- Coverage radius in set covering model

- The cost of establishing subscribers' affairs' agencies

- Demand

Solving the proposed model, 10 points were selected for the establishment of subscribers' affairs' agencies and each 41 demand points was allocated to these 10 points so that urban travelling is balanced.

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