**Paper Review Summary of Reliable Facility Location**

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**Aydin2012**

***Capacitated Reliable Location Problem*** solved by a hybrid approach, underlined by a PSO based sample average approximation algorithm. This model hybridizes the swarm intelligence and SAA method to efficiently solve the CRFLP.

**Goal:** Identify the set of facilities to be opened while minimizing the total cost of open facilities and the expected cost of meeting customer demand from the surviving facilities and the emergency facility.

The proposed hybrid method reuses the embedded information in sample solutions by consecutively solving the sample problems while injecting social learning in the solution process. The swarm intelligence injection is based on the Particle Swarm Optimization (PSO). This hybridization gives an improved result over the simple Sample Average Approximations. The SAA based algorithm is preferred when the sample size is very large. In this hybridization the sample size reduces and solution quality improves at the same time.

This combined approach differs from the meta-heuristics approach to solve stochastic programming problems in two ways. Firstly, the solution methodology is based on SAA where the solutions in the swarm are obtained by exact solution of the sample sub-problems (e.g., rather than an update mechanism such as random crossover operation in GA and velocity update in PSO). Secondly, the swarm learning is incorporated into the objective function by penalizing deviations from a balanced solution by combining the swarm’s best solution found thus far and the swarm’s average solution.

**Solution Methodology:**

In this model the CRFLP is a two-stage stochastic programming problem.

* In the First stage, the location decisions are made before random failures of the located facilities.
* In the second stage, following the facility failures, the customer-facility assignment decisions are made for every customer given the facilities that have survived.

In the scenario-based formulation of CRFLP, let us denote a failure scenario as s and the set of all failure scenarios as S, where s belongs to S. Let ps be the probability that scenario s occurs.

Consider the implementation of the classical SAA procedure in the context of PSO and treat each sample solution as a particle. Then the implementation of SAA shall correspond to iterating the particles (sample solutions) in the swarm (the set of sample solutions) only once and then selecting the best performing particle. In the PSO, however, the particle iterations are contributed for by the particle’s recent memory (e.g., inertia) as well as with the social learning. Hence, in the proposed hybrid approach, we modify the SAA method by continuing the solution of the sample problems (e.g., particles) while injecting the social learning in the solution process.

In the discussed hybrid approach the main challenges is the movement of particles. In traditional PSO movement of particles happens based on Velocity but in this approach

**Li2012**

In this paper author discuss two related models for design of reliable distribution networks

1. a reliable P-median problem (RPMP) and
2. a reliable un-capacitated fixed-charge location problem (RUFL)

Both the problems have the failure probability of the facility as heterogeneous,

* One layer of supplier backup, and
* Facility fortification within a finite budget.

**Solutions**: Lagrangian relaxation

**Problem Area:** transportation logistics for distribution of goods and services from the suppliers to the consumers

In this paper the author has designed a network keeping in mind an increased need for fortification. Once the facility is fortified then we can say the facility is fully reliable. Both models incorporate a finite fortification budget constraint. In the proposed model author assume that the facility failure probabilities are independent and location specific and also considered one layer of supplier backup. Instead of the mention scenario to enhance the network reliability introduce the fortification of selected facilities. On fortifying the facility, the reliability of the network is improved but the procedure results in an incurrence of extra cost. The cost of fortification is independent of facility and consists of two components - *A fixed setup cost and a variable Cost for reliability improvement.* Both the models incorporate a finite fortification budget constraint.

Basics assumption of the proposed model is

* Fortification budget is a constraint
* Assess the rate of return on fortification investment and compare it to that of alternative investment opportunities.
* Periodic fortification improvements so that

Experimental Design:

* The Euclidean distance between nodes i and j was used as the transportation cost dij .
* The failure probabilities qj were randomly generated from U ~ [0, 0.05].
* The fortification setup cost sj was set to 30
* The variable fortification cost rj was randomly generated from U ~ [0, 3000].
* For P-Median problem P= 5, P=8.
* The facility construction cost fj was randomly drawn from U ~ [500, 1500].
* Fortification budget B ranging between 0 and 360.

The investment on fortification will be applicable if the rate of return on investment of fortification can be increased. In this problem it shows that on 49 nodes of demand and fortification investment of 60 will give the maximum return.

**Cui2010**

In this paper author discuss about the Reliable Un-capacitated Facility Location Problem under Risk Disruption. In this work the author designs a supply network model where the network is as reliable as well as cost efficient.

In this model the author designs the network in such a way that If the primary facility (closest to the facility) fails to serve the demand from any demand point, then the next closest facility needs to be chosen. If all the assigned facilities fails to serve the demand from any demand point then penalty cost is charged for that demand. For each demand there are r levels that need to be created, iterating from 0, 1, . . r-1. If all the facilities from 0 to r-1 fail then the penalty cost is charged. This problem is the extension of *snyder2005* where the failure probability of the location is independent and location specific which is different from facility to facility.

**Goal:** Minimize the expected transportation costs in both regular and failure scenarios to balance the trade-off between normal and emergency operating cost.

The discrete Reliable facility location problem is solved by Mixed Integer Programming that computes the optimal facility location and customer assignment. To solve the MIP efficiently for a large number of variables a complex problem, namely, **Continuum Approximation,** is used which predicts the total system cost without the details of the facility location and customer assignment.

In the proposed Optimization problem (RUFL) the objective functions and all the defined constraints are the product of a continuous and binary variable. The proposed model is converted to form a linearization technique, which is then used to solve the problem. The selection of the facility now imperatively designates the closest facility, keeping in mind the facility’s failover probability.

LRUFL problem is solved by Lagrangian Relaxation Algorithm to makes the model more efficient. The LRUFL problem is split into several sub-problem based on individual customer assignment which is again a customer assignment problem. Two techniques are used to solve the Relaxed problem, one is excat algorithm, where a customer is assigned to the facilities, level by level in increasing order of distances and is solved by branch and bound algorithm. Another is the approximate solution which is built in the same mould as the exact algorithm but its worst case complexity is exponential. This algorithm finds the lower bound of Lagrangian procedure.

Similar to the discrete localization problem, the author also introduces the model for continuous metric space using continuum approximation algorithm. This model applies both homogenous and heterogeneous plane, planner coverage area of the facilities.

Customer demands are distributed over a density function. The test instances group in two ways, one is for homogeneous where all system parameter are constants over space and another is for heterogeneous where all the parameters are continuous over space. The system has been built using CA tools which is a valuable tool for sensibility analysis.

**Lee2006**

In this paper author describes the capacitated reliable discrete facility location problem.

Problem Context: Locating base station for cellular communication network.

The Objective of the paper is to determine the number of base stations and their locations such that all users of the cellular network are served with adequate service level. The economic design of the network is a trade-off between cost coverage and service availability. Cost coverage includes the station’s setup cost, fixed cost to lease the land and service could not be measured deterministically due to randomness and dynamic user’s demand. Due to the roaming of a user’s, a base station becomes inactive when it capacity reaches the upper limit. Once the base station is not able to provide the service due to the limited capacity then the nearest facility of the base station will be able to provide the service. In this problem failure of facility or base station notifies the base station not been able to provide the service due to reaches the capability.

The objective function is to optimized consists of two parts, fixed charged to erect a candidate facility, and a weighted sum of the transportation cost from each customer to different facilities when the facilities are un-reliable. The failure probability of the each facility is known from earlier and it depends upon the location. Another assumption is that each demand point or customer has two facilities one is primary, served from base station and another is secondary.

**Solution Procedure:**

The solution procedure is two-fold in the first fold the procedure is a dual ascent procedure, which critically increase the value of each dual variable until it is blocked by any dual feasibility. The second component of the procedure begins when all values of the dual feasible variables are blocked from further increase. If the dual solution satisfies the complementary slackness conditions, the solutions are optimal, and the primal solutions are determined by primal dual conditions. If not then the dual variable are adjusted to improve the solutions. The dual variable that violated the complementary slackness conditions are selected to improve the feasibility. If complementary slackness satisfied, terminated the dual procedure. If the complementary slackness function not even satisfied then branch and bound procedure is employed to complete the search procedure.

**Murali2012**

**Problem Type**: capacitated covering model with chance-constraints to handle demand uncertainty.

**Objective**: maximize the percentage of the affected population that successfully receives the medication. That is, goal is to maximize coverage or minimize unmet demand.

**Problem Area**: Distributing the medicine at the time of emergency in large scale which covers maximum demands.

In this work author describes a capacitated facility location model to decide which facilities to be open as points of disbursement (POD) and how many supplies to make available at each POD in order to maximize the coverage of an uncertain demand in the event of a bio-terror attack.

The above discuss problem is about an uncertainty problem of demands with maximal covering of the demands and developed an efficient solution methods for this optimization problem that allows to solve real sized problems representing a large urban area. In this problem each demand point used several facilities with a given certainty. In this proposed model as demand is not constraint and all the demands not been served from a single facility point due to the unavailability of the particular medicine or lack of stock in PODs.

Three different steps taken to solve the problem they are coverage bound function, deterministic model and chance constraint model incrementally and there experimental results compared each other.

In the solution approach author borrowed a concept of multiple coverage levels which denotes that demands point consumes the service from different facility point with a certain percentage within the different coverage area. The covering model present here allows distributing the demand of one point between multiple facilities located possibly at different coverage levels in order to maximize the amount of demand serviced.

In deterministic model determine which of a set of pre-specified facilities need to be opened when a large-scale emergency occurs.

Now consider the case when the demand for medical supplies at each demand point is not known a-priori that means there are some uncertainty in where the amount of demand that can be assigned to all the facilities within the demand point. In this problem it assume that the possible demand values due to an emergency event follow a random variable for which we know the probability distribution at each demand point. In this work, it assume that the demand generated from the demand points follows a log-normal distribution

In the experimental results shows the merit of using the chance-constrained model to locate facilities, determine their supplies and allocate demand points to the open facilities. It also shows the relative gain in the coverage, achieved by using the chance-constrained model over the deterministic model. Under the best-case scenario, it shows that nearly a 20% gain in coverage by resorting to the locations given by the chance-constrained model.

**Li2010**

Reliable uncapacitated fixed charge location problem (RUFL) seeks optimal facility locations to minimize the one-time investment for facility constructions and the long-run transportation costs for serving spatially distributed customers. The failure of a facility will force its customers to either travel longer distances to obtain service from another facility, or give up service and incur a penalty. Many facility disruption cases exhibit strong spatial correlations, probably because neighboring facilities are likely to be exposed to similar hazards. Such correlations significantly influence the facility failure pattern over space and hence the system operation. Under negative correlations, neighboring facilities tend to back up each other to avoid long distance travels of the customers. Build the model upon the continuum approximation approach to estimate and design the complex system. The structure of the spatial correlation is modeled in a variety of ways to provide flexibility in addressing real-world scenarios.

In this model it assumes that assume that the customers have complete information on facility disruptions and choose facilities for service accordingly. It also assume, for simplicity, that the failure scenario does not change during the time that customers are traveling. At any point of time customer will either visit a function facility within distance if one is available or bear the penalty cost. There are several incremental approaches followed to solve the problem they are

* An infinite and homogeneous plane and the facilities fail independently with an equal probability.
* Building on the results for IHI, discusses how to incorporate correlated disruptions into the framework - conditional probabilities have been used to model general correlations of symmetric binary events. Based on the Pascal’s triangle, probabilities of symmetric disruptions can be represented as the product of facility failure probabilities conditional on the number of neighboring disruptions.
* And further develops the continuum approximation model for finite and heterogeneous space.

Facility failure correlations can be modeled in a variety of ways

* Positively correlated beta-binomial facility failure and
* Correlation induced from shared hazard exposure like flood hazard, earthquake hazard

The proposed model builds on the properties of idealized special cases and solves the problem for general heterogeneous and correlated disruptions. Particularly, spatial correlations have been formulated in a variety of ways to provide modeling flexibility. The model is tested with a series of numerical experiments where the effects of disruption correlations on the location design and cost estimation are discussed.

**Peng2011**

Study the problem of designing a supply chain network, which consists of supply, transshipment, and demand nodes. The aim of this model is to design a supply chain network that performs well in the long run and is able to deal with short-term contingencies efficiently. Instead of the mentioned problem author also discuss clearly about Reliability and robustness which helps to design the model without ambiguity.

Logistics network design problems (LNDP) with facility disruptions. It is nothing but generalization of classical capacitated facility location problem by considering multiple echelons, and makes decisions regarding the selection of suppliers, the locations of factories and warehouses, the assignment of suppliers to customers, and the flows of products through the network.

In this model carefully planned for disruption scenarios that may occur and we have developed a new model. Instead of probabilistic disruption which is known earlier for uncertainty of the facilities here used robust optimization, which provides an alternative way of coping with uncertainty and does not require probabilistic information

Formulate a mixed-integer programming model which incorporates the p-robustness measure in the constraints. The objective is to minimize the total nominal cost, i.e, the total cost when there is no disruption, while restricting the relative regret in each scenario to be no more than p. Here used a scenario-based modeling approach, in which each scenario specifies a set of facilities that fails simultaneously.

Propose a hybrid metaheuristic algorithm that is based on genetic algorithms, local improvement, and the shortest augmenting path method.

The proposed model shows that, with little additional investment in infrastructure, the supply chain can be made significantly more resilient to disruptions, which makes planning for disruptions more attractive from a managerial prospective.

In this proposed model if customer’s demand cannot feasibly meet, we incur a penalty that is proportional to the customer’s demand. It is also possible to choose not to serve a customer if this penalty is smaller than the cost of serving the customer. The penalty may be interpreted as a lost-sales cost or as the cost of serving the customer from an outside supplier on an emergency basis. Model this contingency by assuming that ‘‘emergency facility’’ that has no fixed cost (and is therefore always open in the optimal solution), is never disrupted, and has infinite capacity.

In such type of scenario based approach the number of scenario is dependent the number of facility nodes and for that the total number of scenario will be hugged. Moreover, when the number of scenarios is large, the value of p has to be chosen more carefully in order to maintain feasibility. But in real life to solve the problem user needs to be choosing less number of scenarios. One of the methods is to identify those scenarios which disrupted only 1 facility.

**Solution Approach :** In this integer mixed programming relax the uniform-disruption-probability assumption using a variety of modeling approaches. Our model relaxes this assumption using a scenario-based stochastic programming approach.

Propose a hybrid metaheuristic algorithm which combines a genetic algorithm, local improvement search, and a shortest augmenting path method. A major improvement to the basic GA scheme is that for each generation, we apply a local search procedure called learning to improve the average population fitness. GA encodes values for the locations of the supply and transshipment nodes (the X variables). Once the X variables are chosen, the Y variables can be set optimally by solving jSj capacitated min-cost network flow problems, one for each scenario, keeping the X variables fixed. This provides the objective function value for a given choice of X variables.

**Chen2011**

**Problem Description**: reliable joint inventory-location problem.

**Goal**: The objective of this reliable joint inventory-location problem (RJIL) is to determine the optimal number of facilities and their locations that minimize the expected total cost (including the facility setup cost, the transportation cost and the inventory cost) across all possible facility failure scenarios.

In this paper author propose in this paper a nonlinear mixed-integer model to incorporate inventory ordering and holding costs and a more general customer assignment scheme into the reliable facility location design framework. Propose a customized Lagrangian relaxation approach that decomposes the model into a set of relatively easier sub-problems. A polynomial-time algorithm is developed to solve each sub-problem to its exact optimality despite the presence of nonlinear components.

The RJIL problem seeks to balance between the shipment cost (i.e., by spreading out customer demand across a large number of facilities) and the inventory and the facility setup costs (i.e., by pooling demand at a few facilities). It assumes that each facility, once built, fails independently with an equal probability. Once facility fails, it cannot provide any service and its original customers will be either diverted to other functioning facilities or subject to certain penalty. It also assumes that each customer is allowed to get service from a sequence of level facility. Once the facility fails to provide service the level-r will provide the facility. Once all the facility fails to provide the facility then the penalty cost incurs for the particular demand.

Propose a customized Lagrangian relaxation algorithm to find near-optimum solutions with optimality gaps. To relax the constraint in Lagrangian relaxation algorithm several steps follows. First find the lower bound of the relaxation algorithm which exact solutions approach to obtain the relaxed constraints. Secondly proposes an efficient algorithm to construct near-optimum solutions to the original RJIL problem. The relaxed RJIL problem may be infeasible to the original problem as it may violate the assignment constraints. Violation might be occurred due to customer assigned to more than one facility at level r or customer is not assigned to any facility at any level of r. Lastly standard subgradient methods update the Lagrangian multipliers.

This model suggests that at a higher failure probability, additional facilities can provide better redundancy for reliable service quality against facility failures. This is because when our customers can be reassigned to more back-up facilities, the marginal penalty cost saving from one additional facility can better offset the extra infrastructure investment, thus making redundancy preferable. All cost components except the penalty cost are relatively insensitive to parameter changes, except that the penalty cost increases dramatically with q and decreases significantly with R. We see that the optimal number of facilities is greater when s is larger (which means that the shipment cost gets more weight compared to the inventory cost). When the shipment cost is dominating, more facilities shall be deployed to reduce the average customer traveling distance. On the contrary, when the inventory cost is dominating, customer demand tends to be pooled to fewer facilities, and a customer may no longer be assigned to its nearest operating facility.