OPTIMIZATION OF DISPATCHING SCHEDULE OF READY MIXED CONCRETE (RMC) PLANT FOR MULTI-PLANT AND MULTI-SITE OPERATION CONDITION: A LITERATURE REVIEW

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Abstract- The demand of concrete is increasing drastically due to infrastructure development in developing countries and to fulfil this ever-growing demand, RMC industry plays an important role. As per a report published by ICI in August 2015, if the efficiency at RMC plant can be improved by 10%, it will result into saving on Rs. 2400 Crore per year. To improve this efficiency, optimization of dispatching schedule of RMC truck can be done. The main aim of the research is to determine best suited algorithm to optimize dispatching schedule of RMC plant by using multi-plant and multi-site operation condition. The research also aims to determine various factors affecting dispatching schedule of RMC plant by using transit mixtures. To achieve the aim, various route optimization has been studied and compared. It is concluded that, mixing duration, number of transit mixtures, concrete demand of construction site, distance of construction site, casting duration at site, allowed buffer duration, number of plants and external factors are eight factors affecting dispatching schedule of transit mixtures. It is also concluded that genetic algorithm, a soft computing route optimization tool is best suited algorithm to optimize the dispatching schedule of RMC plant with multi-plant and multi-site operation condition.

Keywords: *Ready mix concrete, Ready mix concrete dispatching, multi-plant multi-site, Optimization techniques, Vehicle Routing Problem (VRP), Genetic Algorithm (GA).*

1.0 INTRODUCTION

Ready mix concrete is the most used construction material as concrete is required to construct residential buildings, commercial building, and infrastructure projects. In-situ concrete or site mixed concrete is not self-sufficient to fulfil the huge demand generated in developing countries like India, Spain, Sweden, etc. Hence, new technology of Ready Mix Concrete (RMC) was introduced in early 20th century to fulfil this demand. Ready mix concrete can be defined as, "concrete mixed at stationary mixture or batching plant as per pre-defined design mix and then transferred to construction site by using transit mixtures in fresh condition" [1]. In order to reduce losses and use complete capacity of RMC plant to gain profit, special emphasis should be given on optimization of concrete deliveries. Multi-plant and multi-plant operation condition of RMC plant provides better use on multi-plants for concrete delivery and provides reduction of total fuel consumption of transit mixtures. To determine the optimized schedule of RMC delivery, algorithms such as genetic algorithm, bee colony algorithm, ant colony algorithm, etc. can be used.

Ready mix concrete dispatching problem is a type of Vehicle Routing Problem (VRP). Vehicle routing problem is an important part of logistical system as it aims to minimize total operation cost and provide vehicle with optimized route to travel [2]. There are many variables In VRP such as VRP with split delivery, VRP with time window, Combined VRP, Multi Vehicle Routing Problem, etc. At RMC plant route optimization is tedious work as most of the decision are taken by RMC planning experts by using past experiences and the industry still lacks use of decision support system. To solve vehicle routing problem at RMC plant, hard as well as soft computing both can be used depending upon the input conditions.

2.0 ROUTE OPTIMIZATION TECHINQUES

Optimization techniques are the way to solve problem based on maximization or minimization of objective function containing multiple or no constraints. If these optimization techniques are used to solve vehicle routing problem to minimize total travel distance or fuel cost, then the optimization techniques are known as route optimization techniques and problem statement is known as routing problem. Dantizig and Ramser were the first person to study Vehicle Routing problem to solve route optimization in 1959 which resulted into reduction of 5% to 20% of transportation costs [3]. The importance of route optimization techniques had increased in last few decades as it can be use to plan distribution systems and logistics and impart economy I transportation. Based on scientific studies, it can be proved that route optimization technique is scientific and reasoning-based technique to solve optimization problems [4]. The resultant optimal route can be defined as, "The shortest route with minimum travel time or fuel consumption or travel distance based on objective function".

Many algorithms have been formulated to solve routing problems known as route optimization techniques. The route optimization techniques are mainly classified as hard computing tools and soft computing as shown in figure 1. Each optimization has its own importance and can be used in various situations to get optimized results.

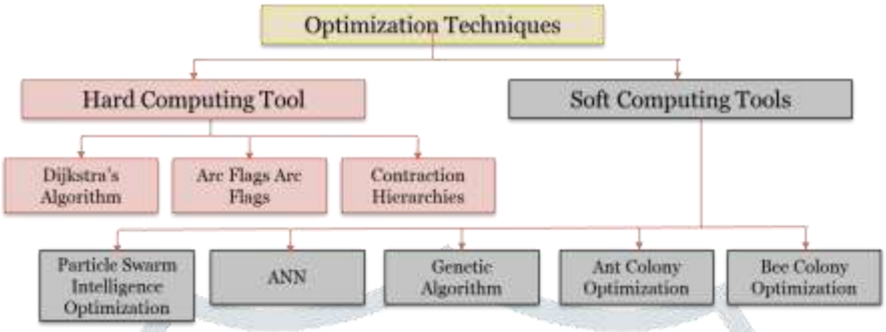

Figure 1. Classification of route optimization techniques

2.1 Hard Computing Tool

Hard computing tool used analytical approach along with reasoning, logic, certainties, etc. to provide optimized results for a particular problem. It uses static data of time, cost, etc. and provides result for static conditions. Hard computing tools are further classified as:

2.1.1 Dijkstra's Algorithm

Dijkstra's algorithm also known as shortest path algorithm developed by Edsger D. Dijkstra (1956) is used to find the shorted route between multiple nodes represented in road network system. The nodes act as a fixed location which cannot be changes until whole simulation is completed. This method is the foundation of all methods to solve vehicle routing problem to automatically determine the minimum distance between points. The used nodes to determine the shortest path from a different node which is than stored and again used to derive the conclusion for the routing problem [5]. The algorithm can be used to solve routing problem with single source and non-negative static data of distance, time, etc. Use of Dijkstra's Algorithm consumes more time as it does blind search for minimum value from all the nodes and is the only limitation to this algorithm.

2.1.2 Arc Flag Algorithm

Arc Flag Algorithm is a modified form of Dijkstra's algorithm which helps in eliminates the use of calculating distance between nodes which are not used to derive for the conclusion. It acts as a signal post and helps in eliminating the limitation of Dijkstra's algorithm. As signal post helps to determine when to stop a vehicle, Arc flag algorithm marks a node which is to be eliminated for further calculations as shortest cannot be achieved by traveling further that node [6]. This method eliminates algorithm to travel between nodes which cannot provide feasible solution and the solution is derives in less time compared to Dijkstra's Algorithm. The method can also be used for pre-processing the data for other algorithms as it can only be used for optimization in static data conditions.

2.1.3 Contraction Hierarchies

Contraction hierarchies are used to determine the shortest route between two nodes in a graph and is mostly used in car navigation system. The result obtained by this algorithm is fast and optimal as it used technique of hierarchy arrangement of nodes at initial stage of problem solving. Significance level of each node is calculated based on which nodes are arranged in hierarchical order to determine the shortest path [7]. After the nodes are arranged in hierarchical order, the nodes with low significant values are eliminated form the algorithm, which results into determining the optimal result which low time consumption. To get fast and accurate results, the combination of above mentioned hard computing tools can be used. A simple combination of contraction hierarchies which pre-processing of arc flag algorithm provides faster and more accurate results and the method is known as CHASE.

2.2 Soft computing tool

Soft computing tool also know as intelligent computing tool uses computational tools to determine the extent of uncertainties, vague concepts and their impression on the optimization problem. Soft computing tool can be used to solve routing problems with dynamic data sets of time, distance, etc. The optimization tool developed by using soft computing tool for solve vehicle routing problem is also known as intelligent vehicle routing tool. Soft computing tools are further classified as:

2.2.1 Particle Swarm Optimization Algorithm

Particle Swarm Optimization algorithm (PSO) is an intelligent algorithm developed by Kennedy and Eberhart (1995) based on social behaviour of bird swarms searching for food [8]. The algorithm simulates the information sharing behaviour between the flock of bird of discoveries and experiences gained while searching food. Algorithm initially develops random population to initialize the algorithm also known as particles. Each particle if evaluated based on fitness function obtained by objective function and constraints of the optimization problem. Every particle in PSO initially floats in problem space and the position and track of each particle is calculated and stored for deriving best solution. After that, particle moves in solution space obtained to evaluate the values based on fitness function and complete process of PSO is represented in figure 2. PSO can be applied to solve multi-objective optimization problems, software testing, minimum and maximum problems, image classification, ANN, gesture recognition, etc [9].

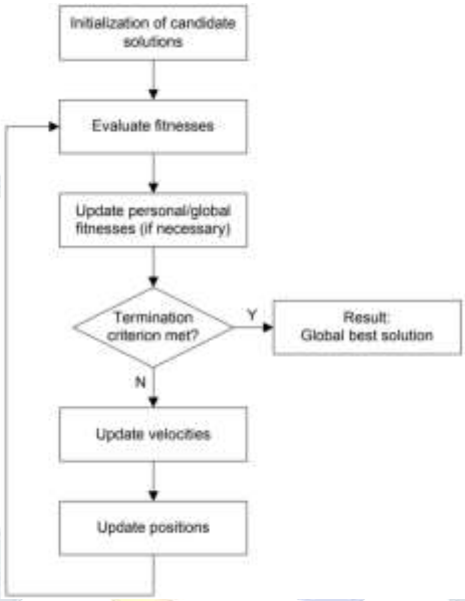

Figure 2. Steps involves in PSO [8]

2.2.2 Artificial Neural Network (ANN)

Artificial neural network was developed Warren McCulloch in 1943 to solve optimization problems and since then, many modifications had been taken place. ANN mimics the process of biological neural form human brain to simulate and provide better solutions [10]. Each neuron has ability to learn, memorize and generalise the solution path to obtain results faster next time. Each neuron consists of dendrites to provide input to cell body which deals with processing. After the data is processed, axon is used to transfer output data between two cell body connections known as synapsis. ANN consists of large number of neurons connected together in series or parallel to process the data and provide optimized solution. The connected network of neurons has to initially trained using feedback loop in order to improve its efficiency.

2.2.3 Genetic Algorithm (GA)

Genetic algorithm is heuristic optimization tool based on Charles Darvin's theory of natural evolution. It is also known as evolutionary algorithm as was used by John Holland (1962) to develop optimization algorithm to solve VRP [11]. The algorithm is based on survival of fittest by which optimized result can be obtained within lower time consumption. The process involved in GA are initiation, selection, cross-over, mutation and survival selection and is represented in figure 3. The data is stored in a set of chromosomes which undergoes cross-over and mutation between two most fit parents to determine the best offspring. All chromosomes undergo survival selection and the process is iterated until optimized result is obtained. As GA contains inherited parallelism, the evaluation of individual chromosome within a set of population is done simultaneously.

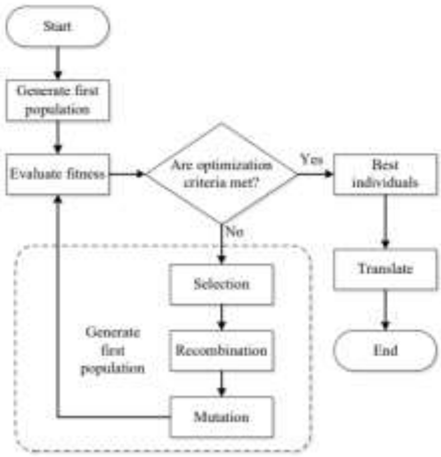

Figure 3. Steps to solve Genetic Algorithm [12]

2.2.4 Ant Colony Optimization Algorithm (ACO)

Marco Dorigo (1992) proposed use of Ant Colony Optimization algorithm based on intuition and behaviours of ants to solve optimization problem [9]. It is a probabilistic technique mimics the way ant seeks path to get food or path of their colony with minimum travel distance. While moving from one place to another, ants deposit pheromones as they are blind. Ant uses pheromone trails to find their nest or food, and the number of pheromones determine the probability of the path to be followed [13]. Figure 4 represents the process of ant leaving pheromone trails to determine shortest path. Ants changes their path when any obstruction occurs in order to determine the shortest path. ACO can be used to solve and get optimized result in travelling salesman problem, Quadratic assignment problem, job shop scheduling, etc.

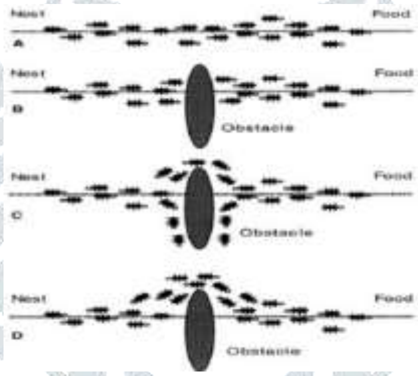

Figure 4. Shortest path by ACO [14]

2.2.5 Bee Colony Optimization Algorithm (BCO)

BCO also known as artificial bee colony algorithm (ABC) was proposed by Karaboga in 2005 to solve various optimization problems by simulating behaviour of honey bees. A swarm of bee colony contains three types of bee performing different functions in the algorithm: employee bee, onlooker bees and scout bees. Employee bee acts as a searching bee, they search for the food and store and transfer the information of food to onlooker bee. After the information transfer, onlooker bees evaluate the source based on fitness function values and select high quality food source [15]. Some bees abandon the regular food source and visit to find different and new food sources, and are known as scout bees. By combining the efforts and analysis of the fitness function, neighbourhood search is performed and process is iterated until the shortest path is determined.

3.0 Ready Mix Concrete Dispatching Problem (RMCDP)

The demand of concrete is increasing drastically due to infrastructure development in developing countries and to fulfil this ever-growing demand, RMC industry plays an important role. As per a report published by ICI in August 2015, if the efficiency at RMC plant can be improved by 10%, it will result into saving on Rs. 2400 Crore per year. To improve this efficiency, optimization of dispatching schedule of RMC truck can be done. Ready Mix Concrete Dispatching Problem (RMCDP) is a type of vehicle routing problem to minimize to total distance travelled by RMC trucks known as transit mixtures to fulfil the concrete demand at construction sites. In last few decades, many researches have been conducted to solve RMCDP with different optimization techniques but, still the there is lack of decision support system in RMC industry. Figure 5 represents the evolution of algorithms to solve RMCDP and optimize the results.

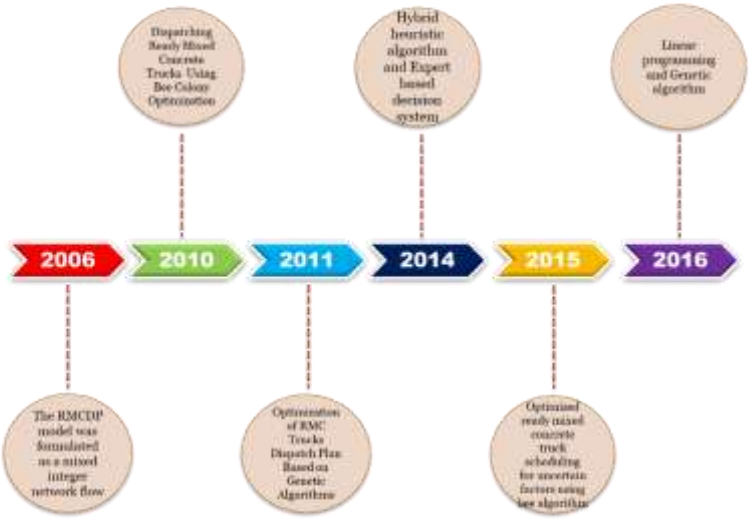

Figure 5. Evolution of optimization technique to solve RMCDP

In 2006, a research was conducted to solve RMCDP by using mixed integer network flow method [16]. The research concluded that, the model can be used for actual work but, the limitation occurred for calculation of delay occurred while transporting concrete. In 2010, research tried to used bee colony optimization algorithm to solve RMCDP and get optimized result. It was concluded that, BCO provides quick and effective results than mixed integer method. Furthermore, the result generated by BCO were of high quality and the computational time required was very low [17]. In 2011, a research was conduct to solve RMCDP with Genetic Algorithm. The research also used integration of SMS technique to gather details of delay and update the dispatching schedule [18]. In 2014 expert-based decision system was analysed based on hybrid heuristic method to calculate its efficiency. It was concluded that 90% of the time decision made by experts at RMC plant make the right dispatching sequence choice, but it is mainly associated by higher transportation cost [19]. BCO with integrated use of uncertainty factors was used in 2015 to optimize the dispatching sequence. In the research paper 12 problems were solved using Genetic algorithm and Bee algorithm to compare the results. It was concluded that, Genetic Algorithm is the most suited algorithm to solve dispatching problem as it provides better result than BCO [20]. In 2016, combination of linear programming with genetic algorithm was used to solve the RMCDP and to determine best suited model. It was concluded, hybrid GA with linear programming provides better result than individual methods [21].

All the above used algorithm is used to solve RMCDP with single-plant and multi-site operation condition of RMC plant. Not much research has been done on multi-plant and multi-site condition for dispatching of RMC concrete. The algorithm which can optimize the dispatching schedule of RMC plant for multi-plant and multi-site condition and give result in minimum time is not yet known.

4.0 Factors affecting dispatching schedule

Ready Mix Concrete (RMC) dispatching operation by using transit mixtures depend on various factors such as, mixing duration, number of transit mixtures, concrete demand of construction site, distance of construction site, casting duration at site, allowed buffer duration, number of plants, external factors, etc.

i. **Mixing duration**
Mixing duration is the amount of time required to mix concrete ingredients as per mix design at RMC plant. The mixing duration depends upon type of RMC plant i.e. manual loading or automatic loading and capacity of RMC plant (CP30, CP60, CP90, etc.).

ii. **Number of plants**
Normally single plant is used to dispatch concrete at all construction sites to fulfil its requirement. Total fuel consumption, number of transit mixture required and interruptions can be used by using multiple plants to deliver the concrete.

iii. **Number of transit mixture**
Transit mixtures are the truck that carry concrete in dry or wet form from RMC plant to construction site. The maximum capacity of RMC truck is 7 cubic meters. So, to fulfil the demand of concrete at various site with no interruptions, optimal number of trucks should be available at RMC plant.

iv. **Concrete demand at construction site**
As the maximum amount of concrete that can be carried by transit mixture is limited to 7 cubic meters, the total number of deliver per site depends upon the concrete demand at that site.

v. **Distance of construction site**
Time of travel is co-related with distance to be travelled by transit mixtures from RMC plant to construction site. Maximum distance that an RMC plant deliver concrete is 25km.

vi. **Casting duration**

Casting duration at concrete depends upon method of casting such as dumping or pumping. It is also affected by the type of structural element to be casted.

vii. **Allowed buffer duration**

Buffer duration is added to include the time consumed by unforeseen condition such as traffic, rain, etc. The maximum buffer should be limited such as the time duration between mixing and dumping of concrete should not be more than 120 minutes.

viii. **External factors**

External factors are the factors which cannot be controlled by human such as breakdown of truck, heavy rain, pump breakdown, accident at road, etc. As the external factors cannot be taken in consideration while planning and to reduce their effects, these uncertainties are included in buffer duration.

5.0 Conclusion

After going through many literatures in field of optimization techniques to solve vehicle routing problem it can be concluded that, soft computing is better suited to solve Ready Mix Concrete Dispatching Problem (RMCDP) with multi-plant and multi-site operating condition as hard computing can optimize problem with single source with static data of distance, time, etc. only and RMCDP with multi-plant condition have multiple sources for transportation. Many researches have been conducted in past few decades to optimize dispatching schedule by using soft computing such as Genetic Algorithm (GA), Bee colony algorithm (BCO), Ant colony algorithm (ACO), etc. But GA provides faster and more promising results than any other methods as it is an evolutionary method and involves process such as cross-over and mutation. It can also be concluded that mixing duration, number of transit mixtures, concrete demand of construction site, distance of construction site, casting duration at site, allowed buffer duration, number of plants and external factors are eight important factors which effect optimization of dispatching schedule with multi-plant and multi-site operation condition of RMC plant.

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