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Ready-Mix Concrete Best Plant Selection and Cost Optimization

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Abstract

Ready-mix concrete (RMC) is a standout amidst the most widely renowned construction material for the development industry over the most recent couple of years. Concrete is a perishable material, so to speak that it hardens after a particular measure of time. RMC isn't created at the creation site where it is essential, as rightly its name suggests. It is delivered by solid concrete plants with particular extents of different materials relying upon the request of the development locales who go about as the clients. Cost of ready-mix concrete is influenced by two imperative components. The first is the crude material cost and the other one is the cost of transporting ready-mix concrete with a blender truck from the concrete batch plant to the development site. Therefore, appropriation of ready-mix concrete from the supply focus to the request focus with least cost is gone for in this task work. In our research work, we propose a linear programming mathematical model for the problem of ready-mix concrete delivery, which proves to be NP-hard, based on transportation algorithm. The objective is to propose a manner through which the best delivery plant is selected for supply of concrete in a certain region from the viewpoint of minimizing delivery cost and increasing cement-industry profits. Data for the study is obtained from, a real companys business process and logistics management. Computational experiments are done using four different methods and conclusions are derived.

***Key Words*:**Ready-mix; concrete; batch plant; linear programming; bestdelivery plant; NP-hard

1 Introduction

The Indian development industry has been customarily labor oriented. The pace of automation in the past had taken a step back because of the availability of cheap labor in profusion, no investment in the capital market and the intensely divided nature of the development business. The level of automation is still around 25%-30% while it is well over 70% in the vast majority of the developed nations [20]. In turkey and numerous other developed nations, on location manual mixingof cement has been banned. The overwhelming Turkey seismic tremor in 1999, in which in excess of 18000 individuals lost their lives as a result of falling solid structures made individuals focus on the RMC quality and its timely delivery [19]. On one side, the concrete batch plants need to organize the production areas and vehicles conveyances, trucks and pumps to get greater profits. On the other side, development locales require consistent emptying and casting to guarantee quality and progress of the construction going on. The new age developments required speed and better quality. Such imperative prerequisites sparked the need to create powerful frameworks for taking care of the ready-mix delivery problem.

RMC, in present day development is a standout amid the most well-known manufacturingresources in development industry and concrete requests are scaling as of late. The concrete market is confronting the two chances of incredible benefit and dangers of rivalry too, from fellow competitors. In this manner how to make more advantages and favorable circumstances ought to be very much concerned.

RMC isn't created at the creation site where it is essential, as rightly its name suggests. Creation happens at plants, from where the ready-mix concrete is transported to the development destinations, utilizing vehicles called "truck blenders" particularly intended to transport concrete.Essentially, concrete is created by water, aggregates and cement. After around 2 hours, depending upon the quickening agents and retarders being used, concrete solidifies and it will get its required toughness and quality [19].

The nature of RMC structures generally relies upon nonstop close coordination between the provider and the developer on location, from requesting the material to releasing and setting up it.Successfully and proficiently conveying RMC to development destinations is an essential issue. The point is to diminish the cost of conveyance process. Hence, there is a dire need to oversee concrete dispatching from a solitary place for a specific district/city. There are numerous RMC producers in the market and the material cost isn't entirely different. In this way, every producer rivals each other on the client benefit fulfilment. Clients are searching for the merchant that can convey RMC as indicated by their necessities, for example, on-time conveyance. One noteworthy limitation of RMC conveyance issue is that RMC must be conveyed to the development site inside certain time window after creation. More often than not, the organizer takes care of RMC conveyance issue based upon his understanding of the whole system and this can cause disappointment from the customersif the truck is in line, waiting for a long time to unload the material. Hence, careful planning of the whole system is very much crucial.It is to determine which plant group would convey concrete in which locale and boost the delivery of RMC. Since RMC conveyanceissue is very perplexing, it draws interests from numerous researchers.

To achieve our goal, these steps are performed: a) determination of constraints and decision variables b) building a mathematical model which appropriate with transportation problem including all constraints c) analyzing the model with

i) CPLEX Optimization Studio Solver

ii) Vogels Approximation Method

iii) Least Cost Method

iv) North-West Corner Method

and rivalling the results obtained. To make the simulation and results realistic, dataset had been obtained from a reputed cement industry for one particular order day.

The rest of this paper is organised as follows: There have been only a few publications in the literature devoted for ready-mix concrete optimisation problem, which have been elaborated in section II. In section III the RMC Transportation Problem is discussed with the help of a detailed example. Section IV describes the proposed linear programming mathematical model, the objective function along with all the constraints involved. Comparison of four different techniques based on transportation algorithm has been done in section V. The numerical tests used to assess the performance of the model and the solutions obtained are explained in section VI. Conclusions followed by future scope of this research work is finally drawn up in section VI and VIII.

2 LITERATURE SURVEY

S. Q. Wang and M. Anson [1] constructed a model based on five types of constraints namely amount of work done by the truck, loading wait time, unloading time, idle time of the truck and time taken to return back to the plant. The model was further enriched by taking into account two more constraints: traffic-considerations and labor cost. However, the transportation algorithm that we have implemented involves only two kinds of constraints namely supply constraints and demand constraints which are explained in detail in section III. C. W. Feng and H. T. Wu [2] after understanding the high complexity of the RMC scheduling problem developed a speedy Genetic Algorithm (fmGA) and in order to find the finest shipping order CYCLONE simulation was used which would reduce the total delaying time. They concluded that it is a very difficult task for the concrete batch plant manager and employees to manually develop a dispatch schedule as soon as they see an order from the customer. Hence, they felt the need to cultivate an effective optimized solution. They worked on optimizing the waiting time of concrete tuck mixers in the queue at the construction site. S. Q. Wang, G. Ofori and C. L. Teo [3] made use of @Risk software tool, and the waiting time of trucks at the construction sites was reduced to up to 11 minutes with its help. They also stated that the way in which trucks arrive at the terminus location is also a very important factor for optimizing productivity at any batch plant. MicroCYCLONE simulation system was made use of by T. Zayed and D. Halpin [4]. Production cost, production time and resources for the truck mixer were determined using contour lines chart and time-cost quantity. In the graph, the feasible region showed the different options that can be chosen to achieve the objective of minimize cost. C. W. Feng, T. M. Cheng and T. H. Wu [5] here an overview of the hereditary algorithm was produced for planning of the RMC trucks. This calculation produces an arrangement of arbitrary numbers which are in typical conveyance and after that sets the shipping status of the considerable number of trucks in understanding to the request expressed. This arrangement of irregular numbers is then balanced in agreement to the pre-set time and amount as given by the end-client and it is then mimicked to get the best enhanced consequence of the truck-blenders delivery. Matsatsinis examined in [6] primarily another part of concrete conveyance which we don't consider here in our work, the directing of pumps, which is fundamentally a multi-station vehicle steering issue with time windows. M. Lu and H. C. Lam [7] developed an in-house computer simulation model to meet the high demand of concrete at multiple sites. It was observed that the use of this system helped to improve the service in terms of delivery and overall utilization of plant resources. L.Ming, X. Shen, H. C. Lam, C. Wu [8] worked upon the closely monitoring and tracking RMC blenders with any of the remote frameworks that are available in the real world. This incorporated approach with the correspondence frameworks helped a lot in the arrangement of truck mixers if the path was found to be very congested. S. Yan and W. Lai [9] introduced a new concept and stated that trucks that are on time are considered as zero additional time. Useful limitations were considered. The model depended on mixed number system issue. The scientific program CPLEX was utilized for the effective numerical programming. In our research work too, CPLEX Optimization will be used for implementing transportation algorithm. It was likewise discovered that this model enhanced the profitability of RMC supply continuously tasks. This model worked successfully with minor deferrals of truck blenders and some postponements of plant, yet in significant occurrences like any of the breakdowns of truck blenders, pumps and so on this model was not workable. L. Asbach, U. Dorndorf and E. Pesch [10] have etched out the fact that the vehicle routing problem is very similar to that of RMC scheduling problem. To handle this, a Mixed-Integer Programming (MIP) model was suggested. However, it was found to be too perplexing to crack. They also point out that fabrication and delivery are highly interlinked as the material created is a perishable one. P. C. Lin, J. Wang, S. H. Huang and Y. T. Wang [11] simulated that the dispatching process of RMC truck churners by associating it with a shop problem with recirculation. This included time windows and demand postponements. Considering the cost of transportation, this model was framed as a multi-objective programming model. An investigation revealed that there were factors divided in intrinsic and imposed constrains referring to the limits that were to be fulfilled during the concrete dispatching process. Truck mixer dispatching was an intrinsic constraint while distribution process was considered as an imposed constraint that should be tried to be fulfilled up to a maximum level during dispatching. Here a recommendation of Just-in-Time practice is put forward to maintain RMC quality. It is also claimed that it is a highly reliable model. S. Sakchai and T. Rujirayanyong [12] built up a bee colony streamlining for the dispatching arrangement of the RMC truck mixers and this model was observed to be moderately superior to anything the model produced with the assistance of genetic algorithm. This model indicated lesser aggregate holding up times when contrasted with the all different past models. This model likewise created more adaptable and capable outcomes to dispatch the RMC trucks. RMC distribution scheduling problem was solved byA. Bells, A. M. Coves and D. L. Santos [13]with the help of the novel Multi-Start (MS) algorithm. It shows how fit the analyzed solution is and is strongly based on planned programming. M. Maghrebi, S. T. Waller and C. Sammut [14] trusted human intelligence for on-the fly decision making. The problem statement that we are dealing with involves a sizable number of variables that are not studied properly. With the results they obtained, it was found that meta-heuristics models were not much better when compared to expert-based arrangement. These also gave a better picture of the whole system. G. Zhang and J. Zeng [15] went for a unique method which had not been taken into action previously by employing a dynamic method. Seeing the qualms in transportation spells this dynamic approach was taken up. It was noticed that the hybrid heuristic algorithm developed was robust and successful for the ready-mixed concrete scheduling problem. The constraint involved in their problem statement is that no orders are cancelled and no new orders are taken up during the day which makes the situation pretty different from the actual scenario that is prevalent.Hanif and Holvoet [16] understood dynamic planning of RMC conveyance issues utilizing delegate MAS that is a bio-roused coordination system for advancement. Discrete Particle Swarm Optimization (DPSO) model was formed by P. Liu, L. Wang, X. Ding and X. Gao [17]. It presented noteworthy savings in cost for RMC batch plants. Fitness values and total waiting times obtained were found to be more proficient as compared to genetic algorithm. In this, the routes are obtained previously with computation time set as constant. However, they havent taken into account that several possible routes might exist from source to destination since it will make the model complex. Depending on the advancement in technology, if it permits then RMC truck-mixers can be installed with GPS systems which will help in on the fly examination.N. Mayteekrieangkrai and W. Wongthatsanekorn [18]point out that customer contentment is ofprominence since the way in which material is manufactured is similar for all industries. On-time delivery is one such criteria that can be set. It highlights the fact that instantaneously inside certain time gap after the formation of concrete it should be dispensed as it loses its pliability and is of no use after that. G Albayrak and U. Albayrak [19] point out the efiiciency of the existing algorithms in place. They discuss the working of Microsoft Excel Solver by considering an imaginary urban area consisting of 4 batch plants and 7 construction sites which act as the customers.

3 RMC TRANSPORTATION PROBLEM

One of the major cost components in RMC business is the transport cost which is close to 30-35% of the realization [20]. Optimization in this can help business in increasing of raw margin. In the following sections we aim to navigate through the current practice thats in place for selection of concrete plant for dispatch, supplemented with observations and suggestions for improvements.

The current process involves individuals, who have gathered experience in the logistics and have good idea about local distances, it is their expertise that the accuracy and optimization of plant selection relies upon. In short, this broadly depends on:

- knowledge of individuals about the area/geography to arrive at distance between site and plants and
- the number of such individuals available.

Consider a case of 10 Plants in a City and 50 orders in a Day, the distance variables which need to be considered for best plant selection would be 50×10. There is full potential of best plant not getting selected considering the number of variables involved.Current practise of measuring individual Plant Revenue and Profitability would be compelling Zone teams to distribute Orders evenly among all plants, ignoring most profitable plant.Despite this process being run in a streamlined manner till now, it was observed that by streamlining the process of Plant Selection for delivery there is a scope of at-least 5% improvement in reduction of Truck Mixer (TM) running to cater same amount of Quantity using same set of plants and TMs [20].

Being aware of the fact that the scheduling process carried out requires multifarious computations, it is intended to base the Plant selection work on a mathematical process by using transportation algorithm.All the site-plant combination for all orders in the city will be suggested by this proposed mathematical process.The Plant proposal will be such that Transportation cost is minimized and Raw Margin is maximized. The RMC transportation problem is explained in detail below with the help of an example.

TABLE 1. DISTANCE BETWEEN PLANTS AND CUSTOMERS

Batch Plants		Customer Site Codes				
		30019695	30020140	30019854	30001851	30020050
	Noida	10	4	12	13	1
	Billimoria	15	9	9	10	5
	Sahibabad	12	13	9	21	15
	Gt. Noida	5	10	13	15	8

In Table I between all customer sites and the various concrete batch plants using Google Maps, the distance matrix is calculated. Best plant selection was done as depicted in Fig. 1 with the help of an application developed in Microsoft Visual Studio which filtered out the top three plants in close proximity to the client. Based on requirement, the top n plants can bechosen and transferred to the transportation algorithm. This would help in decreasing the logistics cost involved. Concrete demands and production capacity of concrete batch plants are created on the basis of actual values obtained from the dataset and shown in Table II and Table III. The demand for one order day involves all types of concrete produced by the industry. Postgresql was used for storing all the tables involved.

TABLE II. CAPACITIES OF CONCRETE BATCH PLANTS

	Concrete Batch Plants			
	Noida	Billimoria	Sahibabad	Gt. Noida
Capacities	90	60	72	90

The purpose is to build a model that covers all demands with the smallest total cost from the sources. Optimizing the quantity of dispatched concrete is important in this problem. Therefore, concrete distribution cost is taken into account as 1 Re per cubic meter in terms of being a unit value.

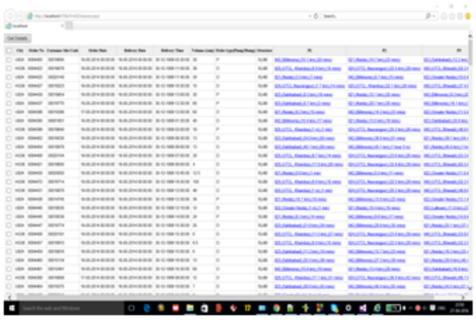

Figure 1. Best Plant Selection

TABLE III. DEMANDS OF THE CUSTOMERS

	Customer Site Codes				
	30019695	30020140	30019854	30001851	30020050
Demands	50	30	30	40	13

4 LINEAR PROGRAMMING MODEL

A transportation issue manages the transportation of merchandise or goods from a few purposes of supply, for example, plants, regularly known as sources, to various purposes of relevance, for example, warehouses, frequently known as point of destination. Each source can supply a settled number of units of the item, more often than not called the limit or accessibility, and every destination has a settled request, typically known as the necessity. It is important to plan shipments from sources to destination with the aim that the aggregate transport cost is least. A linear programming mathematical model can be used to explain the transportationalgorithm and it usually appears in the form of a transportation matrix.

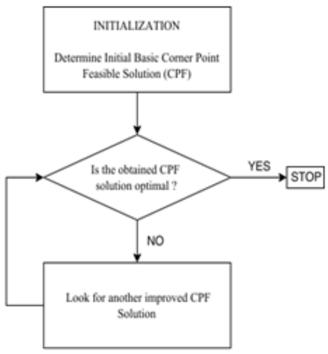

Figure 2. Transportation Algorithm

In particular, a set A of arcs, it is assumed denotes the transportation network, where (i, j) $\in$ A means that there exist a path connecting the supplier i and the customer j.Let costijbe the unit shipment cost on the arc segment (i, j), supplyi signifies the accessible supply at the supplier i and demandj indicates the demand at development site or request at client site j. For instance, in the above example i represents concrete batch plants situated in Noida, Billimoria, Sahibabad and Gt. Noida and j represents the customers (30019695, 30020140, 30019854, 30001851, 30020050).The choice factors are the amounts xij of the product that is transported, it basicallyrefers to the amount of concrete transported from supply point i to demand point j and the problem is to minimize the transportation costs. The decision variables involved cannot take negative values.

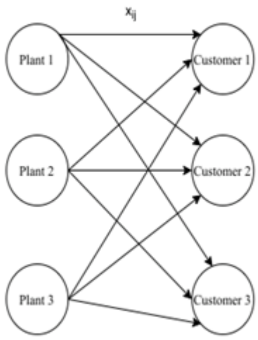

Figure 3. Graphical Representation of Transportation Problem

Minimize costijxijunder the natural constraints:

- The supply supplyi at i should surpass the sum of the demands at all j such that (i, j) belongs to A.

$$\sum X_{ij} <= supply_i$$

- The demand demandj at j must be satiated in the sense that is less or equal to the sum of the supplies at all i such that (i, j) belongs to A.

$$\sum X_{ij} <= demand_j$$

Each individual constraint is described as below: Supply Constraints:

$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} <= supply_1$$
$$x_{21} + x_{22} + x_{23} + x_{24} + x_{25} <= supply_2$$

$$x_{31} + x_{32} + x_{33} + x_{34} + x_{35} <= supply_3$$

$$x_{41} + x_{42} + x_{43} + x_{44} + x_{45} <= supply_4$$

Demand Constraints:

$$x_{11} + x_{21} + x_{31} + x_{41} >= demand_1$$

$$x_{12} + x_{22} + x_{32} + x_{42} >= demand_2$$

$$x_{13} + x_{23} + x_{33} + x_{43} >= demand_3$$

$$x_{14} + x_{24} + x_{34} + x_{44} >= demand_4$$

$$x_{15} + x_{25} + x_{35} + x_{45} >= demand_5$$

5 METHODOLOGY ADAPTED

The model formulated or built is solved and analyzed using four different strategies which are as explained below:

A. IBM ILOG CPLEX Optimisation Studio

The equations of the numerical illustration that appeared in the previous segment are transferred to CPLEX Optimization Studio, and after that the solution is obtained with the assistance of a linear programming code. An optimum arrangement is discovered which covers all requests and sources inside the constraints. The ideal measure of cement transported from supply direct i toward request point j is shown in Table IV.

TABLE IV. RESULTS OF DECISION VARIABLES XIJUSING CPLEX

		Customer Site Codes				
		30019695	30020140	30019854	30001851	30020050
Batch Plants	Noida	0	30	0	0	13
	Billimoria	0	0	20	40	0
	Sahibabad	0	0	10	0	0
	Gt. Noida	50	0	0	0	0

It can be seen that all requests are completely met. Similarly, all source values are ascertained at the most reduced value. As per the outcomes shown in Fig. 3, the aggregate cost of the conveying of RMC is Rupees 1053 for that order day.

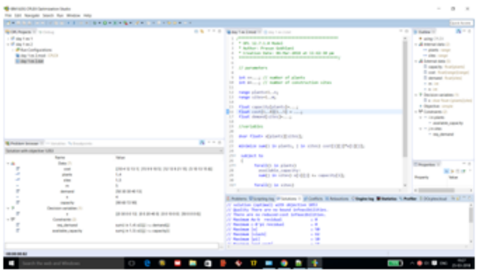

Figure 4. CPLEX Optimization Studio

B. Vogels Approximation Method

The most widely recognized technique used to decide proficient starting answers for taking care of the transportation issue is Vogel's Approximation Method (VAM). The technique includes ascertaining the penalty i.e. difference between the most minimal cost and the second most minimal cost for each column and row of the cost network and afterward allotting the greatest number of units conceivable to the minimum cost cell in the row or the column with biggest penalty. On explanation of unbalanced transportation problem, it prompts the making of a dummy row or column to make the problem adjusted. The customary approach allots zero value to the cost of transferring products to or from these dummies.The solution obtained with the help of Vogels Approximation Method is shown in Table V. According to the results the total cost of delivering the RMC is Rupees 1194 for that order day which isconsiderably more than CPLEX method

TABLE V. RESULTS OF DECISION VARIABLES XIJUSING VAM

		Customer Site Codes				
		30019695	30020140	30019854	30001851	30020050
Batch Plants	Noida	0	30	7	40	13
	Billimoria	0	0	23	0	0
	Sahibabad	0	0	0	0	0
	Gt. Noida	50	0	0	0	0

C. Least Cost Method

It is also called the minimum cell cost strategy, is utilized when the need is to diminish cost for dissemination of concrete material. Different strategies can be utilized if the need is time reserve funds as opposed to cost investment funds.Table VI shows us the result after implementing LCM method. The total cost in this case comes out to be Rupees 1828 for that order day.

D. Northwest Corner Method

The Northwest Corner Method is an empirical which guarantees there is a primary basic realistic solution. The Northwest Corner Method engages in the slightest number of computations.

TABLE VI. RESULTS OF DECISION VARIABLES XIJUSING LCM

		Customer Site Codes				
		30019695	30020140	30019854	30001851	30020050
Batch Plants	Noida	0	0	0	0	0
	Billimoria	0	30	17	0	13
	Sahibabad	19	0	13	40	0
	Gt. Noida	31	0	0	0	0

The initial basic solution using Northwest Corner Method is found to be Rupees 1515 for that order day.

TABLE VII. RESULTS OF DECISION VARIABLES XIJUSING NORTHWEST CORNER METHOD

		Customer Site Codes				
		30019695	30020140	30019854	30001851	30020050
Batch Plants	Noida	50	30	10	0	0
	Billimoria	0	0	20	40	0
	Sahibabad	0	0	0	0	13
	Gt. Noida	0	0	0	0	0

6 RESULTS

The results obtained by the four different techniques used, were shown in the previous section with the help of a numerical example. To elucidate our comparison of the distinctive techniques even more, the results of CPLEX, VAM LCM and NWC for ten different unbalancedtransportation problems obtained from the industry dataset are shown in Table VIII.Here m refers to number of concrete batch plants and n denotes the number of customers. It was also seen that balanced transportation problems are a rarity in the real-world scenario. The step by step details of the ten problems are not shown here due to space considerations.

TABLE VIII. IMPLEMENTATION RESULTS

Problem	m	n	CPLEX	VAM	LCM	NWC
1	2	3	47	47	48	56
2	3	3	550	550	756	816
3	3	3	348	390	3066	771
4	3	3	1098	1102	1192	1126
5	3	4	20200	20300	20650	22500
6	4	3	195	260	245	340
7	4	4	8350	8950	10150	12150
8	4	7	16050	18400	20000	25900
9	5	6	890	890	920	1189
10	6	5	1275	1281	1361	1542

For all the problems considered CPLEX Optimization Studio gave us the best results. VAM gave second best solution in most of the cases and the results were equally good when compared to answers found using CPLEX Optimization for a few of them. However, VAM suffers with a drawback that it will usually allocate amount to the dummy cells that is formed in unbalanced conveyance problem before the other cells in the matrix. The initial solution hence may not be very efficient. LCM and NWC method do not fare well in mostly all the cases as compared to the other two. In future, we can slightly modify the original VAM by ignoring any penalty that involves a dummy row or column.Another arrangement may be that the cost of transportation to or from a dummy point be set to the most astounding transportation cost in the issue instead of to zero esteem. In any case, this may not generally perform better as observed when connected on the five problems solved previously.It is vital to take note of that for any given issue it is hard to foresee from the earlier which of the methods will bring about the best initial solution.

In any case, since all method we employed involve extremely simple operations, it should be possible to easily perform all procedures on any problem quickly and pick the best solution that will achieve our objective

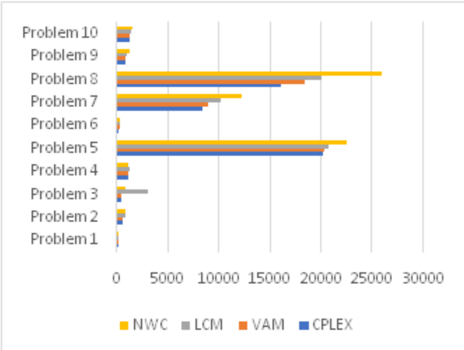

Figure 5. Graphical Representation of Implementation Results

7 CONCLUSION

In this paper, a comprehensive study of the Ready-Mix Concrete delivery problem has been presented. The concrete is mixed without a moment to spare before the stacking of the vehicle at the batch plant, or the crude materials are put in the vehicle and are blended while in transit to the development site. In short, concrete is a perishable decent which can't be put away or created ahead of time. Besides, subsequent to being mixed the blend can't be transported for over 1.5 hours [20]. Along these lines, transportation calculation which accentuates on the purpose of the most minimal conveying cost is utilized as a part of this paper. In majority of the cement industries today, orders are pre-allocated to plants. This involves a lot of human effort considering the number of variables involved. Also, there is no procedure to ensure that best plants are selected from a particular region. The proposed model using integer programming helps solve these problems in such a way that with it, orders will now be decided on the basis of a mathematical process of minimization of distance with transportation algorithm and not pre-allocated. The Mathematical Process takes care to propose Plant with Minimal distance possible considering TMs and Plant Capacity available.The portrayed model and arrangement technique are adequately adaptable to be upgraded for run by the concrete industries. At the same time, practical application of the mathematical system employed in our problem statement, shows that it is significantly more profitable than the generally prevalent old-fashioned method.From the writing as well, it can be inferred that as RMC industry is regarded as an industry having ability of gigantic development, having direct effect on the development of extensive scale extends in creating urban communities. It is profoundly expected that the higher the advancement, higher will be the funds in monetary and timely terms. The route optimization however is a recently foreseen issue of the business, it has a huge extent of research requiring a very streamlined model with an appropriate approach.

8 FUTURE WORK

Some other constraints which are very much prevalent in real-life RMC scheduling scenario havent been considered in this paper. In future, we could have a system in place that ensures that consumers are rated and are given precedence as per theranking that they have got.This would ensure that most profitable customers areserviced before the others. Also, there is no prevailing process to ensure that orders with high raw margin are given priority.

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