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SMART OPTIMIZER SCHEDULING MODEL FOR READY MIXED CONCRETE BATCH PLANTS AND TRUCKS FLEET BY USING GENETIC ALGORITHMS

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Research Paper

Abstract: *Effectively managing the delivery of Ready Mixed Concrete (RMC) for diverse construction projects poses a significant challenge for concrete batch plant supervisors. The formulation of an efficient schedule for dispatching concrete truck mixers is paramount, requiring a delicate balance between practicality and adaptability. The concrete batch plant administrator must establish a productive timetable that aligns activities at the concrete batch facility and construction sites. RMC delivery requests inundate the ready mixed concrete batch plant during specific operational hours, necessitating swift decision-making by the concrete batch plant administrator to create a dispatching schedule that meets the varied requirements of different construction projects. The dispatching schedule time for all batch plants is primarily influenced by the dispatcher administrator's experience and preferences. For instance, a ready mixed concrete batch plant administrator may opt to dispatch as many truck mixers as possible to the busiest construction project. However, while the batch plant waits for the RMC trucks to arrive, this strategy may cause truck congestion at the project site. Clearly, an effective dispatching schedule is crucial for enhancing the overall system efficiency of construction projects and batch plants. This paper initially presents various optimization methods and subsequently analyses the ready mixed concrete system and its transportation strategy, delineating the factors impacting the dispatching schedule. The study then introduces a systematic model employing simulation processes and Genetic Algorithms to optimize the dispatching schedule while minimizing the waiting time of RMC truck mixers at construction projects. The goal of this optimisation is to meet the*

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needs for RMC delivery from various building projects while minimising the impact on casting processes. Ultimately, concrete batch plant administrators will find assistance in organising and managing the dispatching procedure from an automated software that was created utilising the C-sharp programming language and included all pertinent modules. Three cases from the available research were examined, and field data from the DECOM batching facility was applied over the course of three working days to evaluate the software's effectiveness.

Keywords: *Genetic Algorithms, Optimization, C-Sharp language, Schedule, RMC, Batch Plant, Dispatching Schedule.*

1. Introduction

The conceptualization of RMC was initially introduced in 1903 by Jurgen Heinrich Magen's, a German architect, marking the inception of this construction material (Zidan et al., 2013). In the city of Cairo, RMC emerged as the inaugural component integrated into the Egyptian construction industry approximately forty-four years ago. By 2007, the industry witnessed the presence of 14 major cement production companies, a notable increase from the nine recorded in the year 2000. Despite the recent shift towards automated systems in Ready Mixed Concrete production, the temporal scheduling and dispatching of truck mixers in Egypt continue to be manually managed, relying on the expertise of professional (Yan et al., 2008). The operational procedure of ready mixed concrete comprises five sub-processes, delineated in Figure 1. These individual sub- processes are iteratively executed multiple times to fulfil the quantity specifications stipulated by the client's order. The delivery of RMC possesses distinctive attributes: (i) Operating as an on-call process, wherein the production and mixing of RMC align with specific characteristics in response to the client's request promptly upon their call (Environmental Protection Agency, 1977; Feng & Wu, 2006). (ii) Two main types of ready-mix concrete requests are dispatched during peak hours: orders placed earlier and orders placed at the final minute. Consequently, the batching process is frequently occupied, endeavouring to fulfil the requirements of both request types (Feng et al., 2004; Feng & Wu, 2006). (iii) Constricted service regions for RMC trucks are instrumental in determining the revenue outcomes for a batch plant, with the quantity of owned truck mixers significantly influencing financial returns (Feng & Wu, 2006).

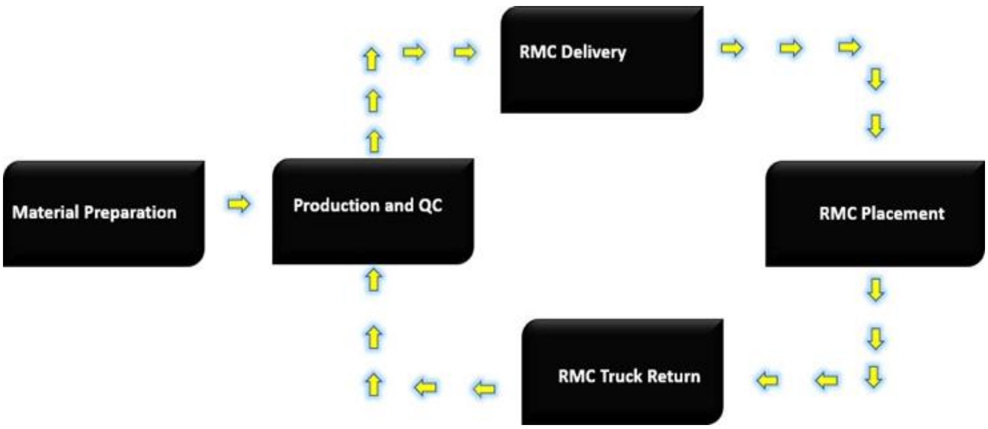

Figure 1: *RMC Dispatching Flow*

Numerous factors exert influence on the scheduling of truck mixes dispatch in the context of ready mixed concrete, encompassing the transit time between construction projects and the central batching plant, the casting duration, and the quantity of requisite deliveries (Environmental Protection Agency, 1977; Feng et al., 2004; Feng & Wu, 2006). (Držečnik & Klanšek, 2023) examined within the context of Ready Mixed Concrete Dispatching Problems (RMCDP), this study delves into the optimization tools grounded in mixed-integer linear programming. The analysis comprehensively explores the attributes of these tools, specifically focusing on their objectives, constraints, and input and output data. The investigation brings to light gap in the existing literature and proposes potential avenues for future research with in this domain (Eppley et al., 2021).

To improve the efficiency of ready-mixed concrete delivery in Egypt, it's crucial to grasp the construction industry's traits and factors affecting delivery schedules. This study aimed to optimize just-in-time delivery schedules from a single batching plant to diverse construction projects. The main goal was to minimize waiting times for concrete trucks at construction sites and prevent interruptions in the casting process. This task is challenging, often relying on the experience of the plant manager.

2. Literature Survey

The delivery of RMC presents a intricate challenge due to its customized mixing for customer requirements, inability to be pre-produced, and the critical constraint of truck transit time not exceeding cold-joint limits to avoid increased operational costs. Hence, optimizing the schedule to meet customer demand is crucial for maximizing profits, prompting various research studies on the complexities of RMC production and truck mixer scheduling. (Zhang et al., 2019) formulates a novel model incorporating a time- space network mechanism and overtime considerations. (Srichandum & Rujirayanyong, 2010) conducted a thorough analysis of the primary factors influencing RMC delivery operations. The dispatching schedule was then optimised using a Bee Colony Optimisation (BCO) model, with the direct goal of reducing truck mixer waiting times at construction sites. An integrated evolutionary algorithm was included in the model that (Blickle, 1996), (Naso et al., 2004) and (Naso et al., 2007)built, with the Genetic Algorithm helping to shape their finding strategy. Furthermore, various heuristic rules were employed to iteratively refine a viable solution that aligns with the specified objectives and constraints. This approach aims to optimize just-in-time production and facilitate the delivery of RMC in an optimized manner. (Zhang & Zeng, 2014) amalgamation of the ready mixed production schedule and the truck mixers schedule was addressed within a unified framework, employing network flow mechanisms. Subsequently, a mixed-integer programming model was formulated to encapsulate this integrated scheduling problem. The optimization of the truck mixers schedule was then undertaken through the application of a hybrid heuristic algorithm. (Maghrebi, Rey, et al., 2014) and (Maghrebi, Periaraj, et al., 2014) undertook a comparative analysis by selecting an evolutionary technique and a numerical technique, namely Column Generation with Robust Genetic Algorithm, for application on a RMC model across diverse scales and under uniform RMC conditions. The outcomes revealed that Column Generation solutions exhibited an average cost reduction of approximately 20%. Furthermore, the Robust Genetic Algorithm demonstrated a throughput approximately 40% faster than Column Generation, with comparable unassigned numbers for both methodologies.

In a different work, (Lin et al., 2010) presented a novel formulation that adapts solutions to the needs of the customers in order to optimally solve the RMC issue with a homogeneous fleet. Ming et al. (2004) introduced a novel optimization approach for concrete plant operations, amalgamating a genetic algorithm-based optimization procedure with the simulation of ready mixed concrete production. The methodology involves the utilization of a computer system to automate the construction simulation model. Subsequently, simulation experiments are conducted to assess resource provisions under specific scenarios, optimizing the system's performance measures. (Lepš, 2004) provided insights into the application of global optimization methods across various Civil Engineering tasks.

(Makul, 2021) proposed a model for overhead bin plants aimed at reducing the production costs associated with recycled concrete aggregate (RCA) while focusing on analysing the financial impacts of delivery operations and supporting the production process. (Taghdisian et al., 2015) addressed RMC problems through a two-step approach, employing a sequential heuristic method to tackle distinct aspects of the challenges involved. (Aziz, 2018a, 2018b) scrutinized an integrated model for evaluating the performance ratio of concrete batch plants, exploring the underlying factors influencing its effectiveness. (Chou et al., 2023) introduced a novel metaheuristic optimization algorithm, subsequently applied to 75 concrete plants to construct an optimal machine-learning model. (Pawar Abhishek & Landage Amarsinh, 2023) formulated a discrete event simulation model tailored for dispatching intervals within a fixed quantity inventory control strategy, aiming to sustain continuous activity while minimizing waste. (Srichandum & Pothiya, 2020) optimized the scheduling of RMC truck dispatches involving multiple plants and construction sites (MPMS), with the objective of minimizing transportation costs under diverse construction constraints.

(Yang et al., 2022) devised a multi-objective optimal distribution model, accounting for time window constraints and demand postponement attributes, specifically addressing the collaboration required among sub batching plants. The model distinguishes between two types of constraints: the timely unloading of trucks and the timely pouring at the construction site. This study enhanced the genetic algorithm's coding method by adopting a hierarchical real-coding approach. The coding operator for each layer can evolve independently, ensuring global search integrity. Additionally, an improved immune operator was introduced to enhance local search performance. Comparative analysis revealed that the results obtained by the enhanced genetic algorithm were 7.05% superior to those of the standard genetic algorithm. (Hettiarachchi et al., 2018) introduced a model aimed at scheduling RMC trucks, with the dual objectives of maximizing both job coverage and profit, while adhering to constraints such as ASTM C94 standards and continuous casting requirements. The proposed solution comprises a rule checker and a scheduler. (Begić et al., 2023) presented an approach facilitating data-driven and schedule- oriented supply chain coordination in the context of demand fluctuations. (Luo et al., 2022) proposed a heuristic algorithm incorporating eight sets of conjoint priority rules for solving the integration problem of RMC production. (Thawongklang & Tanwanichkul, 2016) enhanced the efficiency of the delivery management system by employing a model encompassing production planning and the daily scheduling and dispatching of ready-mixed concrete trucks. This approach aimed to address bottleneck issues in production that subsequently impact the RMC delivery process. (Masoud et al., 2016) implemented a novel heuristic algorithm based on parallel processing, strategically tailored to align with the key characteristics of the Ready Mixed Concrete Dispatching Problem (RMCDP) and effectively model its dynamic behaviour. This approach facilitates efficient truck scheduling for the single-depot RMCDP, aiming to minimize resource assignment to sites and maximize the number of serviced sites. (Velásquez & Isaza, 2017) introduced an innovative approach for designing travel times to construction sites, enhancing its validity and enabling the optimization of production and delivery programs. (Nuntana & Wuthichai, 2015) developed a bee algorithm model to optimize the scheduling problem for ready mixed concrete trucks, considering transportation from a single plant to receivers of various sizes in a large search space. The model employs uncertain factors within the bee algorithm, offering a comparison with the genetic algorithm.

From the survey we observe that there is a room for improvement in the presented domain, which we have tried to cover in this present work.

3. Methodology and Objective

The main goal of the current study is to minimise truck mixer waiting times without interfering with the casting process by optimising the dispatching sequence schedule from a single dispatching facility to several construction projects. The research achieves this objective through various methodological phases, briefly outlined as follows:

Stage 1: Literature Review - A comprehensive review of the literature was conducted, focusing on the efforts made by researchers in recent years within the realm of RMC production. Special attention was given to studies dedicated to optimizing the scheduling from a single concrete batch plant to multiple construction projects. These relevant research endeavours were briefly introduced in this stage.

Stage 2: Analytical Study - This phase of the research involved a comprehensive examination and analysis of the following aspects:

1) A variety of optimisation algorithms, including multi-objective algorithms, specialised algorithms, constrained optimisation techniques, single-objective algorithms, and non-traditional techniques.
2) Components of the mathematical model, such as variable boundaries, objective functions, constraints, and design variables.
3) The best design approach and the method of developing a mathematical model using an appropriate optimisation system. Figure 2 illustrates the detailed steps involved in the implementation of optimal design.
4) Detailed exploration of the GA, which was selected as the optimal algorithm for the study.

The fundamental principles of GAs, involving the maintenance of solutions within a formally encoded population, were elucidated, as depicted in Figure 3.

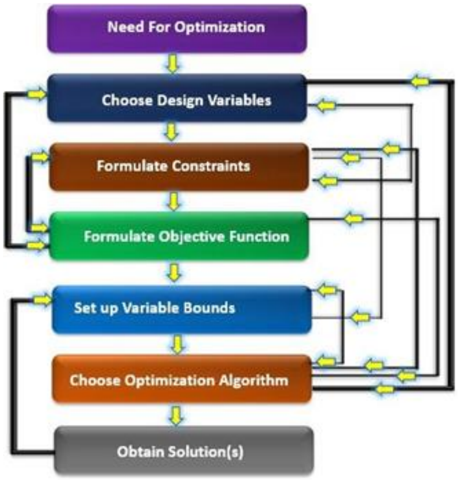

Figure 2: Optimal Design Procedures.

Stage 3: Case Study - The model developed, along with GA optimization, is implemented in the examination of six case studies. Among these, three cases were drawn from existing literature, while the remaining three cases were derived from empirical data obtained from a concrete batching plant located in Alexandria, Egypt, known as the DECOM batching plant.

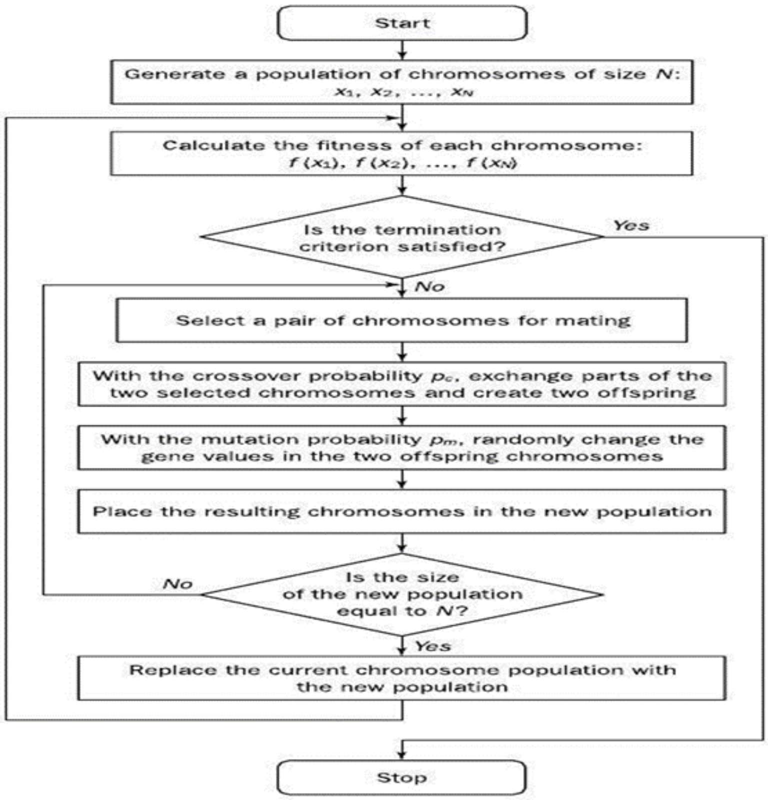

Figure 3: A fundamental flowchart depicting the Genetic Algorithm

3.1 Modeling System

This study centres on an integrated scheduling model, as depicted in Figure 4. The primary components of this model encompass various aspects such as RMC characteristics, factors influencing the dispatching sequence, operating constraints, and the mathematical formulation, as elucidated in the subsequent discussion.

3.2 Ready Mixed Concrete Characteristics

Dispatching RMC possesses distinctive features due to the economic nature of concrete as a manufactured material. Unlike other substances, concrete cannot be pre-mixed and stored in advance due to its rapid solidification. The principal characteristics of RMC in this context are outlined below.

A. An On-Call Process

RMC is manufactured through established formulations tailored to meet the demands of construction projects, as indicated by Darren (2006) and (Elbeltgy, 2014). Furthermore, it is produced promptly upon the request of the general project director, considering the rapid solidification of cement. Because of this, the manager of the concrete batch factory cannot divert truckloads to other building sites until all of the criteria for the quantity of concrete are met and transferred.

B. Peak Hours of Dispatching

A significant proportion of RMC requests exhibit temporal proximity and often arise at the eleventh hour. Consequently, the concrete batch plant experiences heightened activity during specific working hours, leading to a situation where it may struggle to fulfil construction project demands due to an unbalanced and inefficient dispatching schedule.

C. Revenues and Costs

The financial sustenance of a RMC batch plant relies entirely on the revenue generated from product sales. However, the costs associated with raw materials such as aggregates, cement, and sand play a substantial role. Furthermore, the operation of truck mixers holds particular significance in terms of costs, particularly in the context of intermittent casting, which has the potential to compromise the quality of the concrete.

D. Limited-Service Areas and Truck mixers

The deployment of RMC mandates that it be utilized within a timeframe of 100 minutes subsequent to its production by the concrete batch plant, with a designated service area in mind.

3.3 Schedule Dispatching Truck Mixers Affecting Factors

Various causative factors influence the scheduling dispatch for truck mixers delivering RMC, as delineated below:

E. Transporting Duration Between Batch Plant and Construction Projects

The duration of transportation between the examined construction project and the ready mixed concrete batch plant is quantified based on the distance separating them, factoring in traffic conditions and the speed of truck mixers. Consequently, obtaining an exact duration proves challenging, thereby rendering the transportation duration a crucial determinant in the formulation of dispatching schedules for truck mixers. In practical scenarios, historical data can be employed to calculate the average transportation duration (Elbeltgy, 2014).

F. Casting Operating Duration

The amount of time needed to cast ready-mix concrete at construction locations varies according to the kind of work being done, which affects how long it takes to dispatch designated ready-mix concrete truck mixers within the identical project (Feng et al., 2004).

G. Deliveries Needed Number

The number of deliveries required to transport ready mixed concrete to a construction project is contingent upon the volume of order requests, the loading capacity of truck mixers, and the road-bearing capacity as stipulated by regulations (Coves & de los Santos, 2012).

4. The Dispatching Model

The dispatching model, depicted in Figure 4, is delineated into primary components, encompassing output, optimization, simulation, input and constraints.

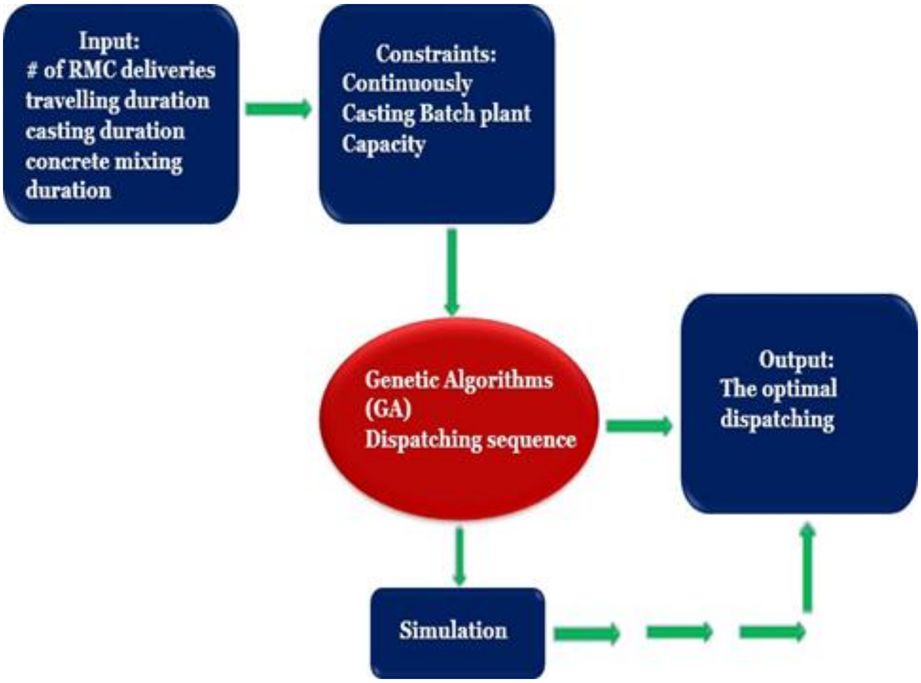

Figure 4: Dispatching Ready-Mix Concrete (RMC) Deliveries: A Model for System Operations.

4.1 Input Parameters

The input parameters of the model encompass various factors, including the transportation duration of truck mixers from the ready mixed concrete batch plant to the designated construction project, and vice versa. Considering factors like how long it takes to mix and load ready-mixed concrete, the acceptable waiting time for delivery trucks without causing delays in the pouring process, the quantity of RMC trucks needed for specific construction projects (depending on the project's size and design), and assuming a constant casting duration (even though it may fluctuate in reality).

4.2 Constrains

The presented model addresses two constraints, namely the continuous casting requirement in construction projects and the capacity of the concrete batch plant.

4.3 Decision Variables

The dispatching sequence is the main decision parameter in the framework, specifically the assignment sequence for each truck mixer to various construction projects. The key consideration in this assignment is the minimization of waiting time for truck mixers within construction projects, with the goal of minimizing interruptions to the casting process as much as possible.

4.4 Output

The output of the system is the optimal sequence of trucks allocated to various construction projects from a single batching plant. This sequence is designed to minimize waiting times for trucks while ensuring minimal disruption to the casting process.

5 Mathematical Model

There are three main phases to the theoretical concept of modelled dispatching.

1st Stage

It's crucial to figure out when truck mixers should leave the batch plant. The orderly flow of truck mixers leaving the batch plant immediately following the completion of the concrete loading procedure is the definition of the optimal batch plant dispatching procedure.

$$FDT = \min_{j=1}^{m} [SCT_j - TDG_j] \quad (1)$$

$$IDT_i = FDT + (i - 1) \times MD, \; i = 1 \ldots N \quad (2)$$

$$N = \sum_{j=1}^{m} K_j$$

In this context:

FDT represents the initial time the first truck leaves.

IDT_i stands for the ideal departure time of the ith dispatched truck mixer.

MD is the duration it takes to mix concrete, specific to the order of truck mixers.

'm' refers to the number of construction projects.

'kj' represents the necessary deliveries of ready-mixed concrete for the jth construction projects.

'N' is the total number of ready-mixed concrete deliveries for all construction projects.

2nd Stage

Finding the best time for the truck mixers to depart is a crucial step in simulating the dispatching process of the truck mixers, as it was determined in Step 1. However, because of the concrete batch plant's restricted capacity, it is possible that there cannot be enough truck mixers available to deliver ready-mixed concrete, and those that have been dispatched might not return.

The simulation process commences with the initial dispatching of the first truck mixers from the plant at a specified time, as per the equations provided:

$$SDTi = IDTi, \text{ if } I \square c \quad (3)$$
$$SDTi = \min [\, TBBi + MD \,], \text{ if } c \square i \square N \quad (4)$$
$$TACji = SDTi + TDGj \quad (5)$$
$$PTFji = SCTj \text{ or } LTj\ (K-1) \quad (6)$$
$$WCji = PTFji - TACji \quad (7)$$
$$LTji = TACji + WCji + CDj, \text{ if } WCji > 0 \quad (8)$$
$$LTji = TACji + CDj, \text{ if } WCji < 0 \quad (9)$$
$$TBBi = LTji + TDGj \quad (10)$$

3rd Stage

The determination of the fitness value involves assessing whether an interruption in the casting of concrete occurs when the duration of waiting for a truck mixer's arrival at the construction project exceeds the permissible buffer duration. Given the imperative to minimize interruptions in concrete casting, a penalty function is introduced to address such instances:

$$P = (\text{Interruptions number}) \times 60 \times 24 \quad (11)$$

$$F = P + TWC \quad (12)$$

6 Genetic Algorithm Model

6.1 Introduction

Presently, the world is equipped with advanced intelligent techniques for problem-solving across various fields, whether dealing with complex or simple issues (Mujahid & Kuruvilla, 2014). Genetic Algorithm, identified as a metaheuristic search method within artificial intelligence, has its roots in the evolutionary process of biological organisms, as defined by (Beasley et al., 1993) and (Goodman, 2014). Operating as a subset of evolutionary algorithms, genetic algorithms necessitate a formal mathematical function or fitness statistics. This is essential as they emulate the concept of solution evolution within populations, optimizing generations stochastically. Goldberg (1989) demonstrated that Genetic Algorithm is well-suited for searching solutions with a high degree of complexity, particularly those comprising extensive attributes that are inherently discrete and nonlinear (Goldberg, 1989).

However, it's important to note that Genetic Algorithms do not ensure optimality, and the results obtained are generally in proximity to optimal solutions.

Additionally, the algorithm employs genes as its fundamental components, with each group of genes referred to as a chromosome. These chromosomes play a crucial role in combining to form a population, as depicted in Figure 5 (Sastry et al., 2005).

6.2 Chromosome Structure

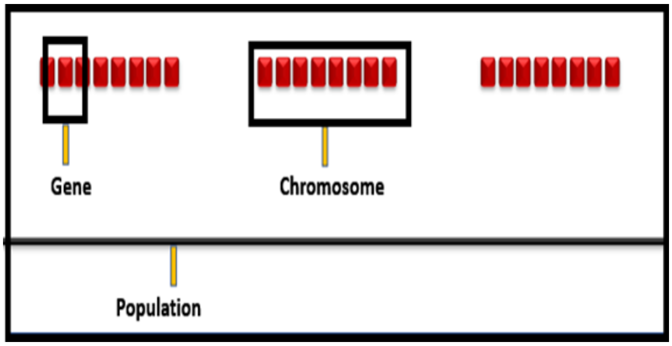

Figure 5: GA Components.

For the genetic algorithm used to solve the optimisation issue, every delivery is a gene contained in a chromosome. Because of this, the size of a chromosome corresponds to the entire amount of distributions that need to be made throughout the day from the batching plant to various construction sites. For the string's genes, a randomly generated key representation is used to prevent the creation of impractical or unlawful solutions, as seen in Figure 6 (Mitchell, 1998).

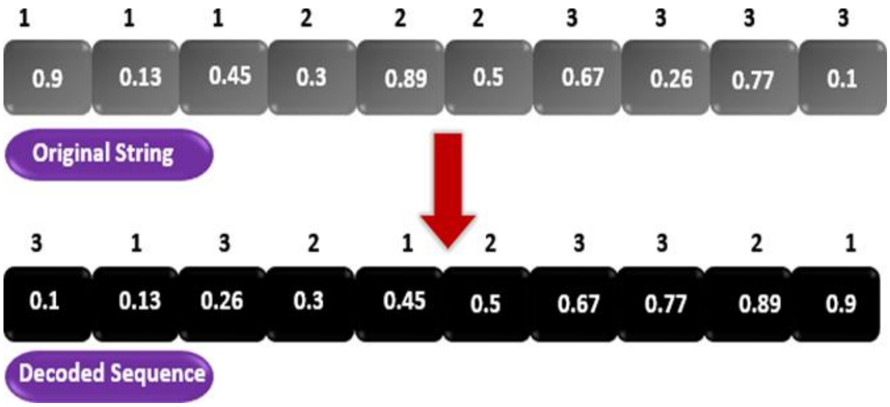

Figure 6: Genes Coding.

7 Fitness Value

Finding the best dispatching order for RMC trucks sent from a single concrete batch facility to several different construction projects is the main goal of the model. The goal of this optimisation is to minimise truck mixer waiting times overall at building sites while preventing casting process disruptions. For this, the modelling approach is used. Equation (12) is used to calculate the associated fitness value for each dispatched sequence in each population based on the genetic algorithm (Sammut, 2021)

7.1 Selection

Various selection methods exist within the genetic algorithm optimization framework, and in this model, proportional selection is employed. Following the computation of fitness values through the aforementioned steps, the optimal fitness solutions are chosen for the subsequent crossover step.

7.2 Crossover

Utilizing the chromosomes' two-point crossover mechanism, two random points are selected from the parents, resulting in the division of each parent into three sections. Subsequently, 2 sections from parent 1 are combined with another section from parent 2 to generate the offspring.

7.3 Mutation

This model incorporates self-mutation by randomly selecting pair chromosomal genes and exchanging their values to create a new progeny.

8 Proposed Software

A mathematical model-based computer programme has been run to produce a well-structured dispatching sequence. The RMDE programme incorporates the concepts of a genetic algorithm for optimisation and is written in C sharp for simulation. The input area and the output area are the two primary components of the programme interface, as seen in Figure 7.

8.1 Input Area

There are three distinct areas within the input field:

1) "Batching Plant Data" focuses on details about the batching plant's capacity, which can be found in table 1.
2) "Project Operation Data" includes specific information about different construction projects that require ready-mixed concrete deliveries, outlined in table 2.
3) The section on "Genetic Algorithms Parameters" contains values for parameters used in the model's genetic algorithm. This covers factors like crossover, mutation rate, population size and generations.

The RMDE program is ready to optimize the dispatching sequence once all the necessary information is input into these sections.

Table 1: Batching Plant Input Parameters.

Mixing Duration	Mixing concrete duration by (minute).
Plant Capacity	The quantity of functional ready-mixed concrete truck mixers owned by the batching plant
Truck mixer Maximum Load	The maximum load capacity of ready-mixed concrete for a truck mixer (m^3).
Projects Number	The number of construction projects that require deliveries of ready-mixed concrete

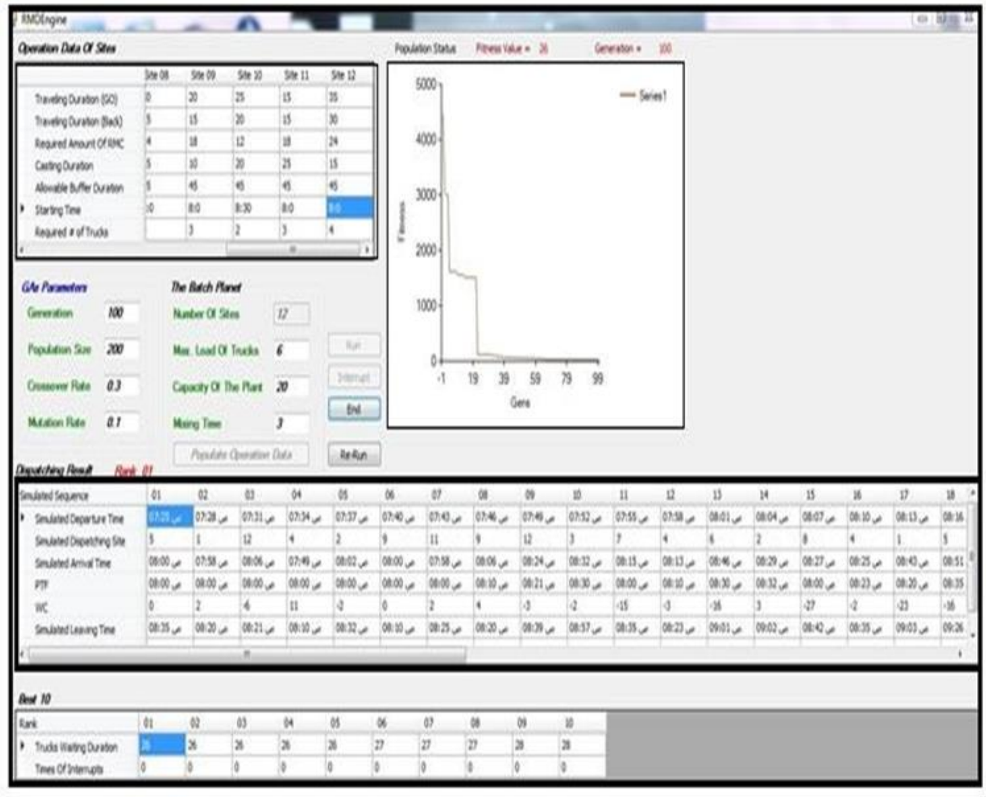

Figure 7: RMDE Program Interface.

Table 2: Construction Projects Input Parameters.

Trucks Required Number	The total number of required truck mixers for each construction project
Starting Time	The initiation time for casting concretein each project.
Allowable Buffer Duration	The maximum amount of time that building projects can be delayed (in minutes).
Casting Duration	Concrete casting time in any building project is measured in minutes.
RMC Required Amount	The cumulative volume of ready-mixed concrete needed for each construction project, measured in cubic meters.
Transporting Duration (Back)	The total time in minutes that truck mixers take to deliver ready-to-use concrete from building sites to the batch facility.
Transporting Duration (Go)	The total time in minutes that truck mixers spend delivering ready-mixed concrete from the batch facility to construction locations.

8.2 Output Area

The RMC Engine's output is displayed in three domains. The Population Status describes how well the Genetic Algorithms are working. The Dispatching Result shows the computer-simulated outcome of the dispatching schedule. This includes the order in which each truck mixer is dispatched, the truck mixers' simulated departure time, and the truck mixers' simulated departure time. Additionally, the outcomes of the top 10 solutions are displayed in the "Best 10" section. Users have the capability to select any feature, enabling the proposed RMDE to exhibit the dispatching schedule solution in the Dispatching Results section.

9 Cases Study

In this work, we looked into more case studies to confirm that the RMDE program is both efficient and accurate. The tests were carried out on a computer with an Intel i3 core and 1GB RAM. The program was used on 4 case studies from existing literature and 3 from real field data. The main goal was to find the best dispatching sequence, aiming to reduce the overall amount of time spent waiting for truck mixers at construction sites while trying to prevent any disruptions in the casting process. One of the cases specifically involved six construction projects.

9.1 Input information.

As previously noted, data that feeds into the programme is separated into three sections: the information regarding the maximum load that trucks can carry and the capacity of the batching plant; the details regarding the construction projects listed in Table 3; and the input data for the genetic algorithm parameters. These variables consist of 200 population members, 100 generations, 0.3 crossover value, and 0.1 mutation rate.

Table3: Input For Batching Plant and Construction Projects.

Project	Kj	ABDj	TDBj	CDj	SCTj	TDGj
1	4	30	35	25	8:30	45
2	3	25	20	30	9:00	30
3	3	20	20	15	8:30	25
4	5	30	25	20	9:30	30
5	4	45	35	15	8;00	40
6	3	40	15	30	10:00	15

The batching plant exhibits a capacity of 10 truck mixers, with a corresponding RMC mixing duration of 10 minutes. Notably, the maximum load capacity for each truck is 6 cubic meters

9.2 Output Results

The RMDE program fine-tunes the input data for a situation involving six construction projects, each having different RMC needs, all supplied from a single dispatching plant. The outcomes, illustrated in Figure 8, reveal that RMDE underwent about 29 generations of exploration to find the best solution. It took approximately 10 seconds to reach this optimum, leading to a total waiting time for trucks of 40 minutes with no disruptions in casting. The fitness value for this optimal outcome is 40. Table 4 & 5 lists the dispatching information for the optimal resolution.

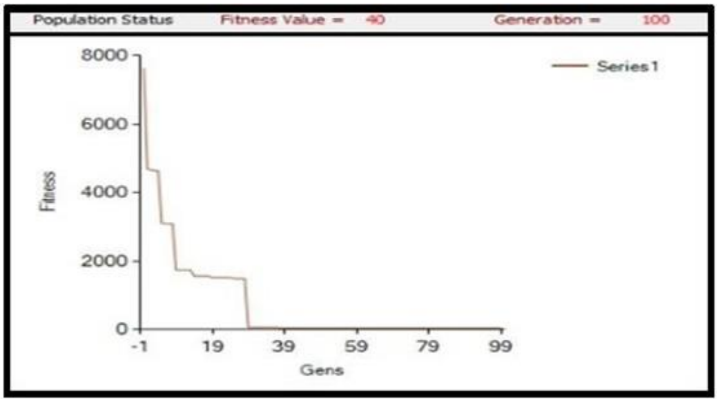

Figure 8: Results of GA Optimization.

Table 4: Dispatching Sequence for Optimal Solution (Time in AM session).

Sequence	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	xiii
SDT	7:20	7:30	7:40	7:50	8:00	8:10	8:20	8:30	8:40	8:50	9:00	9:15	9:20
SD Project	5	5	5	1	5	3	1	3	3	2	4	1	4
SAT	8:00	8:10	8:20	8:35	8:40	8:35	9:05	8:55	9:05	9:20	9:30	10:00	9:50
PTF	8:00	8:15	8:30	8:30	8:45	8:30	9:00	8:50	9:10	9:00	9:30	9:30	9:50
WC	0	5	10	-5	5	-5	-5	-5	5	-20	0	-30	0
SLT	8:15	8:30	8:45	9:00	9:00	8:50	9:30	9:10	9:25	9:50	9:50	10:25	10:10
TBB	8:50	9:05	9:20	9:35	9:35	9:10	10:05	9:30	9:45	10:10	10:15	11:00	10;35

Table 5: Cont. Dispatching Sequence for Optimal Solution (Time in AM session).

Sequence	xiv	xv	xvi	xvii	xviii	xix	xx	xxi	xxii
SDT	9:30	9:40	9:45	9:45	9:55	10:15	10:20	10:25	10:45
SD Project	1	4	6	2	4	6	4	2	6
SAT	10:15	10:10	10:00	10:15	10:25	10:30	10:50	10:55	11:00
PTF	10:25	10:10	10:00	9:50	10:30	10:30	10:50	10:45	11:00
WC	10	0	0	-25	5	0	0	-10	0
SLT	10:50	10:30	10:30	10:45	10:50	11:00	11:10	11:25	11:30
TBB	11:25	10:55	10:45	11:05	11:15	11:15	11:35	11:45	11:45

**Note: SDT=Simulated Departure Time, SD=Simulated Dispatching, SAT=Simulated Arrival Time, and SLT=Simulated Leaving Time.*

10 Conclusion

The research proposed a model that integrates GA optimization and simulation to determine the optimal sequence for ready mixed concrete trucks. The results demonstrated that GA is a suitable method for efficiently finding optimal or near-optimal solutions within a short timeframe, particularly for complex problems. The utilization of a computer program facilitated the discovery of optimal solutions for larger problems in a short time. It is crucial to note that minor incidents in actual operations, such as truck delays, may necessitate some adjustments to the schedule to accommodate real constraint.

10.1 Future Direction

Future research directions may include extending the proposed model to multiple plants. Additionally, modifications to the model could be explored, allowing for variable transporting durations to and from the plant. Integration with GPS technology could provide real-time operational data through the proposed RMDE software**.**

10.2 Research Limitation

Extending the model to multiple plants may introduce additional complexities, such as coordinating and optimizing the delivery schedules across different locations. The logistical challenges and increased variables may impact the feasibility and practicality of the proposed model. Limitations in these resources could impact the scalability and effectiveness of the proposed system. It is crucial for future research endeavours to address these potential limitations systematically and consider the practical implications for the successful deployment of the proposed model and its extensions.

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