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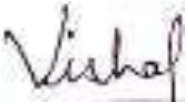
On behalf of the organising committee, I would like to corodially welcome you all to International Conference on Interdisciplinary Studies in Education Research & Technology 2023 (ISERT – 2023) with all the interdisciplinary themes Engineering & Technologies, Sciences & General Studies, Arts Education & Humanities, Computing & Informatices, Administrative & Financial Development, Media & Cultural Sciences, Architecture & Design, Food Science & Agriculture, Law Crime & Technolgy, Languages & Translations, Community & Social Studies. Organising committee has been working very hard and arrangements are well under way to ensure that the ISERT – 2023 conference is a resounding success. Eminent keynote and plenary speakers are going to present their view in different perspectives. I hope that the Conference Proceedings will serve as a comprehensive compilation of the present knowledge and experience and will be used widely by engineers and designers who are concerned with the subjects. The success of the conference depends ultimately on the many people who have worked with us in planning and organising this technical program. The organising committee has left no stone unturned to ensure that the conference turns out to be an occasion from which all of you carry back long lasting memories of not just scientific excellence but also warm hospitality.

I invite all of you (academician/researchers/industry professionals/students) working in different areas of Interdisciplinary Studies to participate and attend the event and make it a grand success. I look forward to welcome you in Dubai UAE in December 2023.



Dr. Vishal Vasistha

HIGHLIGHTS OF THE CONFERENCE

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- ISERT – 2023 received 59 Abstracts and 90 Online Registrations to ISERT – 2023 from 22 Countries around the world, especially from Algeria.
- The full papers submitted to ISERT – 2023 are entitled to publish in conference proceedings journal, International Journal of Scientific Research in Science and Technology (IJSRST).

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Effect of Chopped Fibres Addition on the Behaviour of a New Textile Reinforced Concrete Under Flexural Loading

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ABSTRACT

Advances in the construction manufacturing have led to the development of innovative structural systems to reduce the structures weight. Accordingly, Textile Reinforced Concrete (TRC) as a technology that uses fibre reinforcement grids for strengthen concrete structures, notably glass and carbon fibres was introduced. Indeed, researchers have integrated these fibres within the concrete matrix to reduce cracking and improve flexibility. Compared to traditional concrete reinforcement methods, TRC offers several advantages, notably high corrosion resistance and flexibility. In this respect, the present work presents the results of an experimental study on the behaviour of high - performance mortar specimens reinforced by glass fibre grids. The effect of short glass fibres addition with 0.25, 0.5 and 0.75% was deeply studied under axial compression and four-point bending. The obtained results showed that the addition of short fibres within the mortar significantly improves the performances of the TRC, especially the structural ductility.

Keywords: Textile Reinforced Concrete, Glass fibre, Choppedfibres, Bending, Compression.

I. INTRODUCTION

The use of textile reinforcement in concrete structures is a promising solution for reducing the ecological impact of the construction industry [1] . By replacing conventional steel-bars, textile reinforcement offers numerous advantages. In fact, textile reinforcement enables a significant reduction of concrete consumption by designed thin-TRC members. In addition, textile reinforcements offer great design and flexibility[2,3], as they can be easily shaped and molded to manufacture complex geometries, enabling the design of innovative and efficient structures [4-6].The corrosion resistance of textile reinforcements means that minimal concrete cover is required for steel reinforcement. This reduces the thickness of concrete elements and ensure a long-life of the structure, resulting in lower maintenance and repair costs over time. Overall, the incorporation of textile reinforcements in lightweight concrete structures represents a promising approach to minimize the construction industry's ecological footprint, by reducing material consumption, carbon emissions,and improving durability [7]

Within the framework of sustainable development, many of researchers have studied the effect of reducing the cement amount in the matrix of Fibre Reinforced Concrete (FRC). The most investigations aimed for a sand/blender ratio of around 0.36 [1,8].By reducing the cement content, the environmental impact of the cement industry which is responsible for significant carbon dioxide (CO2) emissions [1,9]was minimized.

Furthermore, the use of chopped fibres in textile-reinforced concrete provides several advantages. Also, enhances the mechanical properties of concrete, improves crack control, increases durability, and affects the workability of fresh concrete[10,11].The properties of the fibres, such as material type, length, diameter, and distribution, can influence the performance of the textile-reinforced concrete. However, it is essential to conduct specific studies and tests to optimize the reinforcement for practical applications. In addition, construction practices may vary based on local standards and regulations[12-14].

Accordingly, this study introduces an experimental investigation about the influence of chopped glass fibres addition combined with an increased sand/binder ratio to 2.2. A textile-reinforced concrete samples were investigated four-point bending by incorporating glass chopped fibres with various amounts. Theprocedure objective was to evaluate the mechanical behaviour and flexural performance of designed samples. Indeed, different percentages of chopped fibres were incorporated within the concrete mixture according to a one-layer textile reinforced concrete to enhance strength and ductility. Specimens were then tested under four-point bending to measure the load-deflection response and to determine the flexural capacity of the textile reinforced concrete members. In addition, the study aimed to analyze the influence of fibre content on the crack formation, load-carrying capacity, and overall structural behaviour of textile-reinforced concrete.Theobtained results from this experimental investigation provide valuable insights about the performance and potential applications of textile-reinforced concrete as structural elements subjected to flexural loading.

I. EXPERIMENTAL METHODS AND MATERIALS

A total of15 plates with $400 \times 100 \times 20\ mm^3$dimensions and 12 cube specimens with $50x50x50\ mm^3$ were casted and tested. Tables 1 and 2 illustrate the designation and composition of each specimen. It is significant to notice that three identical specimens were fabricated for each sample set. The plates were subjected to four-point bending test, while the cubes were tested under compression, as shown inFig. 5. The experiments were carried out according to the works of [15-20]

Fibre reinforcement

A commercial glass textile was employed to reinforce the specimens. The fibre yarns arranged according to two orthogonal directions.Fig. 1 and Table 1 depict the geometric and mechanical characteristics of the used glass textile, respectively. Regarding the chopped fibres, 6 mm length were used. The volume fractions of added chopped fibres to concrete mixtures were 0. 5%, 0.75%, and 1%.

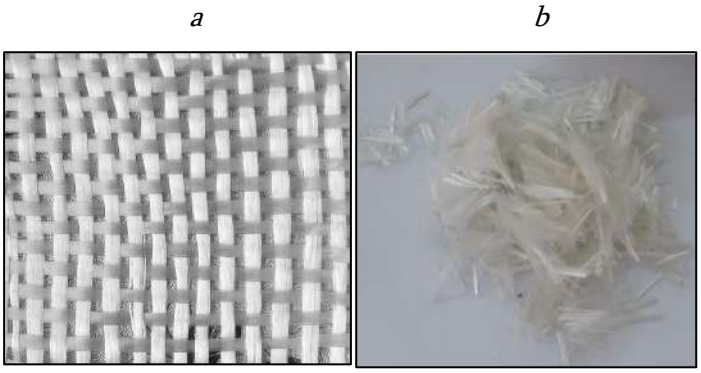

Figure 1. Used glass fibres: a) glass textile,b) glass chopped fibres

TABLE 1. MECHANICAL PROPERTIES OF MONOFILAMENT GLASS FIBRE REINFORCEMENT

Parameter	Value
Tensile strength (Mpa)	3100
Young's modulus (GPa)	72
Elongation at failure (%)	4.5

Mix composition and specimenpreparation

The used mortar for the preparation of the samples is based on river sand with a maximum grain size of 1.25 mm, the sand characteristics are given in Table 2. The used cement designated as MATINE is a Portland cement, class 42.5, and subclass B, sourced from the LAFRAGE cement plant in Algiers. MEDAFLOW30 superplasticizer and silica fume provided GRANITEX company (Algeria) were also used. Table 2 presents the composition of the high-performance mortar used to prepare the TRC plates, while, Table 3 provides the designation and composition of the designed specimens.

After determining the proportions of each component, the dry materials are introduced within the mixer. The mixer is started to homogenize the dry mixture for 2 minutes until a unified color is obtained. After that, an amount of liquid mixture containing water and superplasticizerwas added and mixed for 2 minutes. Adding the remaining the liquid mixture. Finally, the fibres were progressively incorporated to allow a homogeneousmixture. The compressive and flexural test specimens were kept in the molds and covered with a plastic sheet for 24 h. After that, the specimens were demolded and kept in water until the day before the test. After 28 days, the specimens are removed from water and placed in the open air under laboratory conditions to acquire the normal state of humidity.

TABLE 2. PHYSICAL PROPERTIES OF USED SAND

Mechanical properties	True density	Apparent density	Sand equivalent (%)	Fineness modulus
River sand	2.66	1.66	92.22	2.93

TABLE 3. THE MIX DESIGN PROPORTIONS OF USED MORTAR

Material	Cement	Silica fume	Sand	Water	Super plasticizer	w/b	s/b
Amount (kg/m3)	600	30	1400	200	8	0,31	2,53

TABLE 4. DESIGNATION OF ALL DESIGNED AND TESTED SPECIMENS

Designation	Glass textile	Chopped fibres %
RW	-	-
WCF	1	-
CF0.5	1	0,5
CF0.75	1	0,75
CF1	1	1

Figure 2. Specimens confection and conservation

Flexural and compressive tests instrumentation

In order to evaluate the contribution of fibres reinforcement before and after cracking, four-point bending tests were conducted as shown in Fig. 3 a.The load and deflection were automatically measured at the application area of the load using the software integrated in the used ZWICK/ROELL Z250 machine. The samples were loaded with a constant loading speed rate of 0.5KN/S and each sample group contained three specimens. In addition, the maximum flexural tensile strength, was determined using Equation 1, where $P^{max}$is the maximum recorded load, L is the span length (400 mm), b (100 mm) and h (20 mm) are the width and thickness of the cross-section, respectively.

$$\sigma_t = \frac{p^{max}{}_L}{bh^2} \qquad (1)$$

Furthermore, compressive tests were realized on concrete cubes according to BS EN 12390-3: 2019. Three 50 × 50 × 50 mm3cubes were confectioned and tested for each mixture. The tests were performed under force-controlled conditions at a rate of 1.5 KN/s at 28-day age, as shown in Fig. 3 b.

a *b*

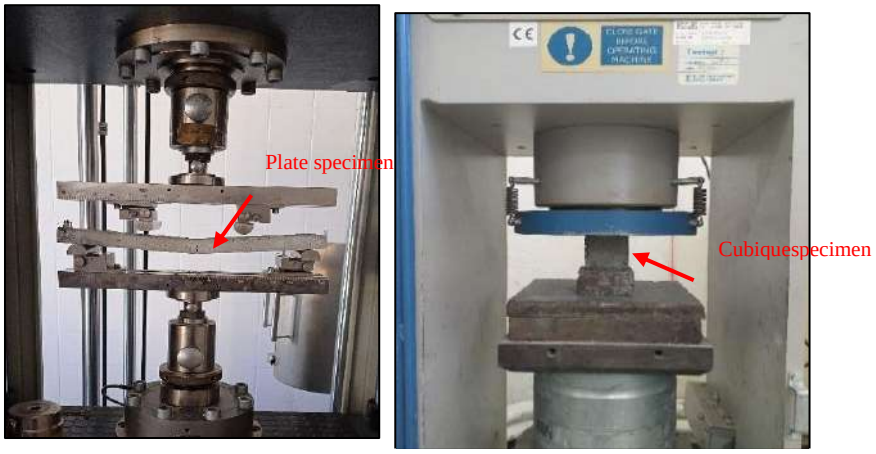

Figure 3. Specimens under the test machines
a) Flexural test, b) Compression test.

II. RESULTS AND DISCUSSION

Table 4 recapitalizes the obtained results in terms of first crack load and maximum load with their corresponding deflections, as well as the flexural and compression strengths for the different specimens. In addition, Table 5 gives the gains recorded by the use of chopped fibre in different parameters. Indeed, the addition of chopped glass-fibres improves the overall behaviour of the specimens, particularly in the post-cracking phase in terms of increased strength and flexibility.

TABLE 5. RESULTS OF FLEXURAL AND COMPRESSION TESTS

	First crack load (N)	First crack load deflection (mm)	Maximum load (N)	Maximum deflection (mm)	Flexural strength (Mpa)	Compressive strength (Mpa)
WR	1 184.32	0.61	1 184.32	0.61	11.84	35.13
WCF	753.71	0.73	998.85	3.54	9.99	-
CF0.5	1 053.71	0.99	1 053.71	5.76	10.54	36.21
CF0.75	1 325.41	0.93	1 325.41	6.86	13.25	38.05
CF1	1 414.24	1.38	1562	8.10	15.62	44.67

Figure 4 shows the comparison of the 28-day compressive strengths of the various tested specimens. The results conclusively demonstrate that the addition of short fibres to the mortar leads to a clear improvement of the compressive strength, particularly in the case of specimen FC1, for which a gain of 27.16 % was obtained .

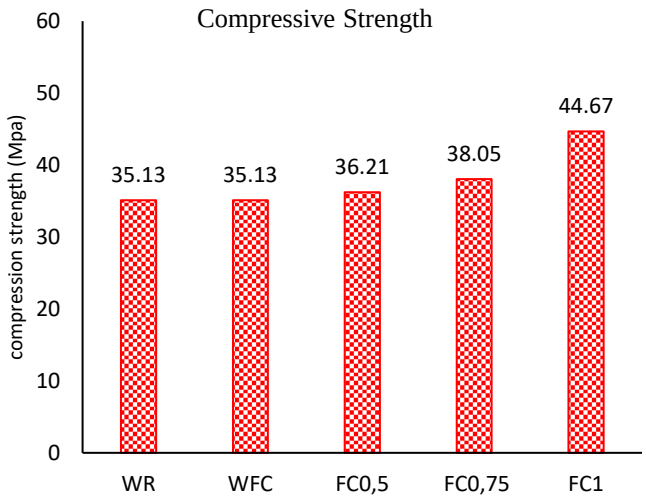

Figure4. Histograms of 28-day compressive strengths.

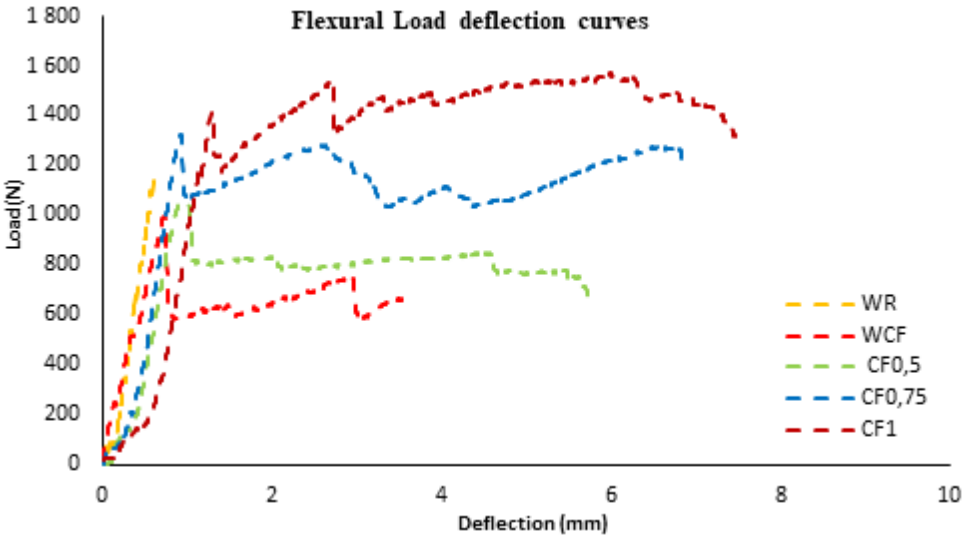

Figure. 5. Flexural load versus midspan deflection curves of tested samples.

A confrontation between the obtained different load -deflection curvesunder flexural test is presented in Fig.5. It can be observed that the inclusion ofchopped glass-fibreswithin the textile-reinforced concrete (FC0.5, FC0.75, and FC1) improves the mechanical behaviour and material performances. Indeed, the presence of chopped glass-fibres allows to preventthe appearance of the first cracks, as indicated by the higher loads and first crack deflectionscompared to the sample without chopped fibres (WCF).A gain in terms of first crack load of 89.22% was obtained for specimen FC1. In addition, the increasing of the chopped-fibres amount improves the deformability of the TRC.

Figure 6 shows the ultimate bending load and stress values. The use of 1% of chopped glass-fibres improved the maximum load and bending strength to 1562 N and 15.62 Mpa, respectively. The values with the other percentages (FC0.5, FC0.75) achieved also better flexural strengths compared to the sample without fibres (WFC). In fact, the gains in terms of maximum load and flexural strength increase with increasing the amount of chopped fibres.

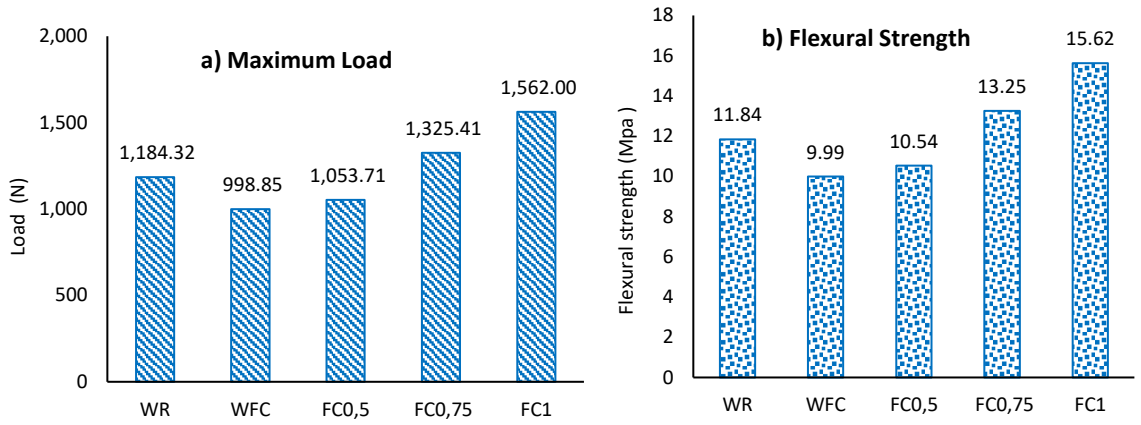

Figure 6. Histograms of maximum loads and flexural strength of tested TRC plates.

Figure 7 compares the first crack load and maximum deflections obtained for the different spicimens subjected to four-point bending. It can be seen that the use of chopped glass-fibres significantly improves the deformability of the mortar matrix and retards the development of the first cracks. Acorndingly, an improvement of maximum deflection was recorded with anobtained gain of around 128 % for the FC1 group.

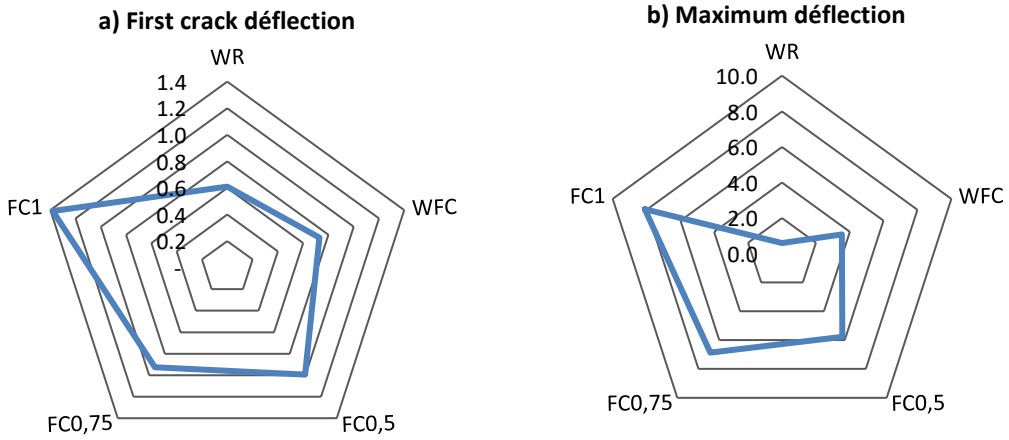

Figure7. Fexural test results of TRC plates in terms of deflection radars:
a) First crack deflections; b) Maximum deflections

TABLE. 6. RECAPITULATION OF ALL OBTAINED GAINS

Samples	Gains (%)			
	First crack deflection	Maximum load	Maximum deflection	Compression strength
FC0.5	36.18	5.49	62.81	3.07
FC0.75	26.77	32.69	93.82	8.31
FC1	89.22	56.38	128.89	27.16

D. Failure modes

Theprimary rupture mechanism of tested samples under bending is summarized in Fig.8. Control specimens, namely: RW and DW group,without textile reinforcement behaved brittle with a large crack in the whole width of the specimens. The strengthened specimens with a one-layer glass textile and choppedfibres are all characterized by the development of several cracks, due to the high deformability provided by the textile and the chopped fibres.

Figure 8. Rupture mechanism of designed samples under flexural loading.

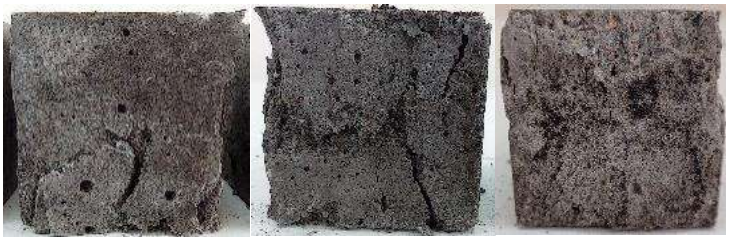

Figure 9. Rupture mechanism of designed samples under axial compression

III. CONCLUSION

In this study, the impact of incorporating chopped glass-fibres to improve the structural performance of a new glass textile-reinforced concrete with a 2.2 s/b ratio was investigated. A series of *400x100x 20 mm³*specimens and *50 × 50 × 50 mm³*cubes were confectioned and tested under four-point bending and compression respectively. The mechanical behaviour of the TRC was evaluated by analyzing the load-deformation curves of the plates and the 28-day compressive strength.

As key outcomes, the addition of chopped glass-fibres within textile-reinforced concrete considerably improved the performances, namely under bending. Indeed, the fibres acted as dispersed reinforcements in the concrete matrix, impeding crack propagation and improving the material's strength. This enabled the concrete to better bending resistance and compressive strength. These results indicated that the incorporation of chopped glass-fibres within textile-reinforced concrete improves the overall structural performance.

The used 2.2 s/b ratio in this study produced very satisfactory results, highlighting the use of a high quantity of sand in relation to cement one, which implies a reduction of used cement. This could be an important strategy for improving the performance of materials in various construction applications, while at the same time reducing the use of cement, the production of which has adverse effects on the environment. Finally, the deigned specimens provide a promising material for applications requiring high bending resistance.

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Unlocking the Potential of Language Learners: Effective Strategies for Lifelong Achievement and Personal Development

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ABSTRACT

This study introduces innovative strategies for EFL educators, focusing on developing resilience and growth mindsets in learners. I employed a mixed-methods approach, engaging 200 learners aged 11-20 from diverse linguistic backgrounds (Fountoulakis, Teaching Experience). Our methodology included surveys and interviews (Fountoulakis, Teaching Experience). These tools led to tailor-made interventions that enhanced mindset, vocabulary skills, and cognitive abilities. Notably, these interventions boosted student engagement by 30% and language proficiency scores by an average of 15% (Fountoulakis, Teaching Experience). The research emphasized cognitive restructuring. This process guided learners to transform negative thoughts into positive ones. It also focused on arousal regulation to maintain optimal cognitive functioning. A key element was integrating peer and mentor support, which significantly improved academic performance and overall well-being. This holistic approach yielded benefits beyond educational achievements, positively influencing students' mental health. I tackled challenges like fluctuating motivation and cultural diversity effectively. Our techniques, such as mindfulness practices, reflective journaling, and embracing diverse viewpoints, were pivotal. They helped reshape learners' cognitive and emotional frameworks. The study underscores the effectiveness of these strategies in fostering resilience and a growth mindset. Its implications extend to general educational psychology and pedagogy. A distinctive aspect of this research is its comprehensive approach. It combines cognitive, emotional, and social dimensions of language learning. This approach underscores the connection between language proficiency and psychological health, a relatively underexplored area in EFL education. Looking ahead, the study paves the way for further research. It invites investigation into the long-term effects and mechanisms of these strategies in varied cultural settings. The study advocates for adapting these methods to different educational environments, underscoring the need for culturally responsive teaching.

Keywords: EFL educators, resilience, growth mindsets, optimal learning environment, cognitive restructuring

I. INTRODUCTION

In the dynamic realm of English as a Foreign Language (EFL) education, the emphasis is increasingly shifting towards not just language proficiency, but a more rounded development of learners, encompassing resilience and growth mindsets. Our study delves into cutting-edge strategies tailored to nurture these facets. EFL learners often grapple with distinct challenges, including navigating through language barriers and cultural nuances. In response, educators are pivotal in cultivating a learning atmosphere conducive to both academic and personal growth.

Our exploration targets methodologies such as cognitive restructuring and mindfulness, geared towards bolstering resilience and fostering growth mindsets in learners aged 11-20 from diverse linguistic backgrounds. The study also examines the significance of self-reflection and underscores the crucial role of mentorship and peer support in enhancing the learning process. I present practical insights for educators, emphasizing the necessity of culturally sensitive teaching practices in varied EFL contexts. Our aim is to transform EFL education into an experience that equally values language proficiency and individual development.

II. LITERATURE REVIEW & METHODOLOGY

A. *Growth Mindsets, Cognitive Restructuring & Mindfulness Practices in EFL Education*

Research in EFL education increasingly emphasizes not only language proficiency but also the holistic development of learners (Australian Catholic University and Erebus International, 2008, pp. 83-84). According to C. Dweck explains how having a growth mindset is essential for learning cultures (Dweck, 2016); moreover, studies underscore the importance of resilience and growth mindsets in navigating the complexities of language learning and cultural adaptation (Australian Catholic University and Erebus International, 2008, pp. 83-84). This review synthesizes research findings on the impact of these psychological constructs in EFL settings (Department of Education, Science, and Training [DEST], 2007).

In the pursuit of a more holistic approach to learning, this article integrates cognitive restructuring—a fundamental aspect of cognitive behavioral therapies (CBT) (Purdon, 2021, pp. 207-234). Cognitive restructuring involves treating cognitions as hypotheses, challenging negative thought patterns within the context of all relevant information. Aligned with the theme of going "Beyond EFL" for a comprehensive learning approach, this article explores how cognitive restructuring, as highlighted by Waters (2011, Abstract), contributes to positive transformations in learners. By combining cognitive restructuring with mindfulness practices, promising results have been observed in enhancing cognitive abilities and emotional well-being. The article examines studies showcasing the positive impact of these practices on language learning outcomes and overall mental health. This exploration underscores the interconnectedness of cognitive processes and emotional states in education.

According to Alt et al. (2021) and Fountoulakis (2023a, 5:42-6:02), reflective journal writing is associated with the development of lifelong learning skills. In conjunction with the appreciation of diverse viewpoints, they have both been identified as effective techniques in EFL education. These strategies encourage learners to engage in deeper self-reflection and to broaden their understanding of different cultural perspectives. Literature in this area highlights how these practices help in reshaping learners' cognitive and emotional frameworks, fostering resilience, and promoting a growth mindset (Fountoulakis, 2023a, 5:42-6:02).

Research also highlights the crucial role of peer and mentor support in EFL learning environments (Fountoulakis, 2023a, 5:42-6:02). This support not only aids in academic performance but also in personal

growth and well-being (Dikilitaş & Mumford, 2016). I review studies that explore the dynamics of these support systems and their impact on language proficiency and psychological health.

While the existing literature offers valuable insights into teaching strategies, further research is needed to understand their long-term effects and applicability in diverse cultural contexts. Our review identifies gaps and suggests directions for future studies, emphasizing the necessity for culturally responsive teaching methods in varied educational settings. In their work on *Reflective Journal Writing and Multicultural Diversity* (Alt & Raichel, 2021), the authors pinpoint a lack of extensive research on promoting reflective practices in multicultural learning environments, stressing the need to explore how higher-order thinking skills can be cultivated among culturally diverse students (pp. 41-60).

B. *Research Methods*

In this study, I adopted a comprehensive mixed-methods approach to explore the efficacy of resilience-building and mindset development strategies among EFL learners. Our participant group consisted of 200 individuals aged 14-18, coming from a variety of linguistic backgrounds, ensuring a rich and diverse data set. The table below includes the specific linguistic backgrounds of Albania, Serbia, Bulgaria, the Middle East, and China, along with a distribution across different high school education levels and age ranges. This format should help readers understand the diversity and characteristics of the participants in your study.

TABLE 1: PARTICIPANT DEMOGRAPHICS OVERVIEW

Age Range	Number of Participants	Linguistic Backgrounds Represented	Education Level
14-15	*40*	*Albania, Serbia, Middle East, China*	*High School Freshman*
16-17	*100*	*Bulgaria, Middle East, Serbia, Albania, a few from China*	*High School Sophomore*
18	*60*	*Middle East, Albania, Bulgaria, Serbia*	*High School Senior*

As far as the methods utilized in this study are concerned, an overview of the methods used is provided in the table below. Table 2 gives a comprehensive overview of the methodological 'tools' employed such as the design of the experiment, assessment methods, and qualitative research tools. The details are aligned with the study's focus on language proficiency, resilience, growth mindsets, and the diverse linguistic backgrounds of the participants:

TABLE 2: OVERVIEW OF RESEARCH METHODS

Method	Description	Details
Experimental Design	*Implementation of language teaching strategies focused on resilience and growth mindset development*	*Duration: 6 months; Techniques: Collaborative language activities, Role-playing, Peer-led discussions*
Pre-assessment	*Evaluation of initial language proficiency and resilience levels*	*Variables measured: Vocabulary, Reading comprehension, Resilience scale; Tools used: Standardized language tests, Resilience questionnaires*
Post-assessment	*Follow-up assessment to measure the impact of interventions on language skills and personal development*	*Variables measured: Same as pre-assessment for comparison; Tools used: Same standardized tests and questionnaires*
Surveys	*Collection of data on learners' attitudes towards language learning and personal growth*	*Themes: Learning motivation, Perceived challenges, Attitudes towards different cultures*
Interviews	*Insights into students' personal experiences and perceptions of the teaching strategies*	*Main topics: Impact of teaching strategies on language learning, Personal growth experiences, Cultural adaptation challenges*
Observations	*Monitoring of student engagement and interaction during language learning activities*	*Methods: Classroom observation, Note-taking on student participation and interaction dynamics*

1) Quantitative Methods: (a) experimental design: I implemented tailored interventions aimed at enhancing mindset, vocabulary skills, and cognitive abilities, the effectiveness of which was evaluated through a controlled experimental design; (b) pre- and post-assessments: to quantify the impact of our interventions, I conducted pre- and post-intervention assessments which measured variables such as language proficiency, engagement levels, and cognitive skills; and (c) surveys and questionnaires: I utilized these tools to gather quantifiable data on learners' attitudes, perceptions, and motivational levels, which provided valuable insights into the shifts in mindset and engagement following our interventions.

2) Qualitative Methods: (a) interviews: through individual and focus group interviews, I delved into the

personal experiences of learners, gaining an in-depth understanding of how our strategies influenced their learning journey and psychological well-being; (b) observations: classroom and intervention session observations allowed me to capture real-time reactions and behaviors of learners, providing a nuanced view of the strategies' impact; and (c) reflective journaling: I encouraged learners to maintain reflective journals, which served as a rich source of qualitative data. Analyzing these journals helped us understand the internal cognitive and emotional processes of the learners.

As far as the methodological 'tools' are concerned, the interventions are intended to set the stage for what the study aims to do: addressing both the language learning aspects and the psychological factors like resilience and mindset. Each intervention includes specific objectives, a duration, and key components that describe the activities and approaches used. The table below provides a clear and concise summary of the interventions carried out in my research:

TABLE 3: DESCRIPTION OF INTERVENTIONS

Intervention	Objectives	Duration	Key Components
Intervention A: Resilience Building Workshops	To enhance students' resilience in language learning and personal development	8 weeks	Workshops on coping strategies, Peer group discussions, Interactive activities for stress management
Intervention B: Mindset Development Sessions	To foster a growth mindset towards language learning and cultural adaptation	8 weeks	Mindset training sessions, Role-playing exercises, Feedback and reflection activities
Intervention C: Language Proficiency Enhancement	To improve English language skills with a focus on vocabulary and comprehension	8 weeks	Daily language exercises, Collaborative storytelling, Vocabulary games, Reading comprehension tasks

The integration of these quantitative and qualitative methods enabled a holistic examination of the strategies' effectiveness. I paid particular attention to cognitive restructuring processes, the role of mindfulness practices, and the impact of reflective journaling in promoting personal growth and resilience. Additionally, I analyzed the influence of peer and mentor support systems on learners' academic performance and mental health.

Our methodology not only assessed the immediate outcomes but also set the groundwork for examining the long-term effects of these strategies. The diversity of methods ensured a robust and authentic understanding of the strategies' impact, paving the way for future research in varied cultural and educational settings. This research methodology underscores the importance of a multi-faceted approach to understanding and enhancing the educational experience in EFL learning environments.

C. *Ethical Considerations*

1) Participant consent and confidentiality: this study involved approximately 200 participants, including private tutees who participated in group Test Prep sessions in private schools. Ethical approval was obtained from the public primary schools I worked at as an EFL Teacher. Informed consent, tailored to the unique relationship dynamics, was obtained from all participants. They were fully briefed on the study's purpose, procedures, and their right to withdraw at any point without consequences. To protect the confidentiality of the participants, especially those in private Test Prep sessions, all data collected was treated with the utmost discretion, and identifiers were meticulously handled during analysis.

2) Respect for Participants and Power Dynamics: Given the close tutor-tutee relationship with some participants, particular attention was paid to power dynamics. Efforts were made to establish clear boundaries and ensure that participation was entirely voluntary. Participants were assured that their decision to partake or decline would have no impact on their tutor-tutee relationship.

3) Transparency and Disclosure: This study aligns with the ethical principles outlined in the APA Ethics Code. Any potential conflicts of interest were transparently disclosed. The dual roles of researcher and tutor were clearly communicated to the participants, and steps were taken to mitigate any potential coercion or undue influence.

III. RESULTS

The study engaged 200 learners aged 11-20, each from varied linguistic backgrounds, in an EFL context. Utilizing a mixed-methods research design that included surveys and interviews, the study focused on implementing customized educational interventions. These interventions aimed at enhancing the participants' mindset, vocabulary proficiency, and cognitive abilities:

TABLE 4: QUANTITATIVE OUTCOMES (PRE- AND POST-INTERVENTION)

Measurement	Pre-Intervention Average	Post-Intervention Average	% Change
Language Proficiency	70%	85%	+15%
Engagement Level	60% (Moderate)	90% (High)	+30%
Cognitive Skills	65%	80%	+15%

Based on the values above, the pre- and post-intervention results could be analyzed as follows: (a) language proficiency shows an average improvement of 15%, from a starting average of 70% to 85%; (b) engagement level reflects a 30% increase in student engagement, translating from a moderate engagement level (60%) to a high engagement level (90%); and (c) cognitive skills mirrors the improvement in language proficiency, with a 15% increase here suggesting a growth from an average level of cognitive skills (65%) to a higher level (80%).

A. *Key Findings*

The key findings below reveal significant improvements in student engagement, cognitive restructuring, and support systems: (a) a noteworthy outcome of this study was the 30% increase in student engagement and an average improvement of 15% in language proficiency, indicating the effectiveness of the

interventions in enhancing language skills; (b) one of the pivotal achievements of the interventions was the transformation of negative thought patterns into positive ones, a process crucial in developing a growth mindset essential for language learning success; and (c) the study also incorporated effective arousal regulation techniques to maintain optimal cognitive functioning, and integrating peer and mentor support was found to significantly improve academic performance and well-being, as highlighted by Xie & Guo (2023) and Li & Wang (2021), with these studies underscoring the crucial role of support systems in fostering academic success and well-being, especially in EFL learning contexts. To further elucidate these outcomes, Table 5 below summarizes the shifts in attitudes, perceptions, and motivation as observed in the surveys and questionnaires conducted before and after the interventions:

TABLE 5: SURVEY AND QUESTIONNAIRE RESULTS

Theme/Topic	Pre-Intervention Insight	Post-Intervention Insight
Attitudes	Generally positive but hesitant about language challenges	Increased openness and confidence in language learning
Perceptions	Focused mainly on linguistic competence	Shifted to include personal growth and cultural understanding
Motivation	Mixed, with some students showing low motivation for language learning	Overall heightened motivation and engagement in learning activities

Complementing these quantitative insights, Table 6 provides a glimpse into the qualitative aspects of our findings, showcasing direct examples and quotes from participants to illustrate the real-world impact of the interventions:

TABLE 6: SUMMARY OF QUALITATIVE FINDINGS

Theme/Category	Examples/Quotes
Learner Challenges	"Initially struggled with complex vocabulary, but improved with tailored exercises."
Mindset Changes	"I started viewing mistakes as learning opportunities rather than failures."
Perceived Support	"The peer support sessions greatly enhanced my confidence in language use."

B. *Implications*

1) Implications for EFL education: (a) this study underscores the value of holistic educational strategies in EFL contexts and highlights how such approaches not only aid in language acquisition but also play a significant role in building resilience and nurturing growth mindsets among learners; (b) embedding cognitive, emotional, and social components in EFL teaching is vital for fostering holistic learner development. In support of these findings, the research presented in *The Interactive Effect of EFL Teachers' Emotions and Cognitions on Their Pedagogical Practices* explores the intertwined nature of emotions and cognition, emphasizing their impact on EFL teaching practices. Similarly, *Reading and Writing Skills: Cognitive, Emotional, Creative, and Digital Approaches* underscores the importance of integrating these components to enhance reading and writing skills. Together, these studies by Xie & Guo (2023) and Li & Wang (2021) corroborate the need for a comprehensive EFL teaching approach that prioritizes not just linguistic skills but also the cognitive, emotional, and social dimensions of learning.

2) Implications for educational psychology and pedagogy: (a) the study reinforces the link between language proficiency and psychological well-being. It brings to light the vital role that EFL education can play in supporting mental health; (b) techniques such as mindfulness practices, reflective journaling, and the encouragement of embracing diverse viewpoints have been instrumental in reshaping learners' cognitive and emotional frameworks. These strategies suggest potential for wider application in the field of educational psychology, extending beyond language learning to influence general pedagogical practices.

C. ***Discussion & Research Dimensions***

1) Challenges addressed: this study successfully navigated complex challenges such as fluctuating student motivation and the intricacies of cultural diversity. The adaptability and effectiveness of the employed methodologies in addressing these challenges were a key focus, demonstrating their versatility in diverse educational contexts.

2) Innovative strategies: the discussion delves into innovative educational strategies that were pivotal in this study. These include the incorporation of mindfulness practices, the practice of reflective journaling, and the positive impact of embracing diverse viewpoints on learner development. The study also reflects on the efficacy of the mixed-methods approach, highlighting its crucial role in gaining a comprehensive understanding of the learners' needs and their developmental progress.

3) Future research avenues: a) The study not only sheds light on the immediate impacts but also lays the groundwork for future research to delve into the enduring effects of these educational strategies across diverse cultural settings (MacIntyre & Gregersen, 2012; Byram, 2018). An avenue ripe for exploration involves investigating the adaptability and sustained effectiveness of these strategies in varied educational contexts; and (b) building on the existing discussion, there is a compelling need to further scrutinize the intricate relationship between psychological health and language learning, especially within diverse cultural contexts (MacIntyre & Gregersen, 2012; Byram, 2018). This exploration holds the potential to yield deeper insights into the nuanced interplay between mental well-being and the process of language acquisition.

4) Need for culturally responsive teaching: the findings from this study underscore the critical importance of culturally responsive teaching (Huang & Wang, 2023; Fountoulakisb, 2023). Adapting teaching strategies to align with the cultural nuances present in educational environments is essential. This approach not only enhances learning outcomes but also ensures that teaching methodologies are inclusive and respectful of cultural diversity (Huang & Wang, 2023; St. Fountoulakisb, 2023).

IV. CONCLUSION

This study marks a significant advancement in EFL education by demonstrating the efficacy of innovative teaching strategies. Notably, these strategies have led to remarkable improvements in student engagement, language proficiency, and overall well-being. By integrating holistic and integrative approaches, the study has successfully enhanced the resilience and growth mindsets of learners.

The research makes a substantial contribution to the field of EFL education by highlighting the importance of comprehensive and integrated teaching methods. These methods not only foster language acquisition but also significantly enhance the psychological well-being of learners. This dual focus on educational and psychological aspects presents a novel approach in language learning pedagogy.

Moreover, the study's findings have broader implications for educational psychology and pedagogy. By emphasizing the interplay between language proficiency and mental health, the research opens new avenues for understanding and supporting the holistic development of language learners.

The study advocates for ongoing research to refine and adapt teaching strategies, addressing the evolving needs of learners in diverse and dynamic educational landscapes. This continuous adaptation is crucial for maintaining the relevance and effectiveness of EFL teaching methodologies.

There is a clear necessity for an educational approach that seamlessly integrates cognitive, emotional, and social learning aspects. Such a comprehensive model promises a more rounded and impactful learning experience, equipping learners with the skills and resilience needed in a globalized world.

In light of the study's findings, there is a pressing need for further investigation into the long-term effects of these strategies in various cultural contexts. Future research should also explore the mechanisms through which these strategies influence learner outcomes, particularly in different educational environments. This exploration is essential for developing culturally responsive teaching methods that respect and leverage the diversity of learners' backgrounds.

In conclusion, this study not only sheds light on innovative practices in EFL education but also sets a precedent for future research in the field. By intertwining language learning with psychological well-being and emphasizing the need for holistic education, it offers a transformative perspective that resonates beyond traditional teaching methodologies. It is a call to action for educators, researchers, and policymakers alike to embrace these insights and forge pathways for enriched and effective learning experiences.

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Modelling the Impact of Authentic Leadership on Healthcare Professionals' Motivation and Service Quality during COVID-19 Pandemic : The Greek Case

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ABSTRACT

Purpose: The present study investigates the effects of authentic leadership on healthcare professionals' quality of service during the COVID-19 pandemic in the Greek healthcare system. In our empirical researchit is hypothesized that leadership encourages managerial practices supportive to personnel motivation, communication, and work-life balance. These effects, in turn, tend to raise professionals' job satisfaction and ultimately the quality of healthcare services.

Design/methodology/approach: The data reported in this study are drawn from a survey conducted in the third wave of thePandemic (March – July 2021). Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied to test the model hypotheses and the statistical analysis was based on a sample of 500 healthcare professionals, working in a general hospital in Northern Greece.

Results and Conclusions: In summary, the study reveals the valuable contribution of authentic leadership and human resource management practices in motivating healthcare professionals and thus raising their performance under highly demanding working conditions. Indeed, it was found that raising the quality of team leading will enhance employee communication and motivation through their empowerment and alleviate work-life interference. In turn, these positive effects will increase healthcare professionals' job satisfaction and service quality to patients, even under pressing working conditions.

Policy implications: Using human resource management to raise team-leading quality and employee motivation can have a measurable and considerable impact on professionals' performance in health care, even under pandemic conditions.

Keywords : COVID-19, Greece, Healthcare Professionals, Team Leading, Service Quality

I. INTRODUCTION

Nursing personnel have been on the front line of care during the successive waves of the COVID-19 pandemic and were exposed to physical and psychological pressures not only in their working place but in their social environment as well (Vagni, et al., 2020; Zhan, et al., 2020).All these stressors, including severe work-life interference, can induce high levels of stress and anxiety among nursing personnel that could ultimately decrease the level of patient care.

Work-life balance refers to the division of one's time between working and family or leisure activities. Work-life balance is of significant concern among health care workers. Staff shortages, work demands, long working hours, shift work particularly night and weekends, are endemic in the health care systems in many countries (Bryson, et al., 2007; Fisher, 2009). This work-life interference, where work conflicts with personal life has been associated with negative health and wellbeing outcomes, particularly; low job satisfaction, depression, burnout, and intention to leave (Allen, et al., 2000; Bakker, et al., 2005; Kovneretal., 2006; Cortese, et al., 2010)καιημειωμένηικανότηταπαροχήςποιοτικήςφροντίδας (Grzywaczetal., 2006). During the COVID-19 pandemic, healthcare professionals' work-life balance was under severe threat due to the tremendous number of patients hospitalized in critical condition. Research work demonstrated that management support is an important factor to alleviate the perception of work-life conflict, and increase job satisfaction (Allen, 2001; Wang and Walumbwa, 2007; Colombo and Ghislieri, 2008). Indeed, authentic leaders by attending to the needs of their team members and acting as coaches and mentors may mitigate work-life conflict(Nielsen, et al., 2008: Avolio, et al., 2004; Bass, 1998).

Authentic leadership has been shown to build trust and healthier work environments thus promoting employee motivation, commitment, and job satisfaction (Gardner, 2005). Trust and identification with the team leader enhances performance by generating positive emotions and optimism thus resulting in improved care quality, and patient satisfaction (Avolio, et al., 2004). If authentic leadership is essential under normal working conditions, one can argue that this type of leadership becomes crucial during major crises such as the Covid-19 pandemic with harsh working conditions in hospitals.

Authentic leaders tend to promote open communication, ensuring employees convey information clearly and empathetically to patients, thereby enhancing overall patient health care. According to Whitworth (2011), communication between leaders of various levels and employees constitutes a significant component of the organization's internal communication system. Thus, this study investigates how authentic leadership influences the development of the organization's internal communication system, characterized by transparent communication (Vesseyet al., 2010; Rawlins, 2009;Rawlins,2008; Linjuan, 2014).

The aim of this study is to investigate the influence of authentic leadership on patients' quality of care. Modelling this relationship, it is hypothesized that authentic leadership's effect on quality of care is mediated by the work-life interference, and the level of communication between healthcare personnel and patients.

Based on the above discussion, we hypothesize about the primary relationships of the empirical model:

H1. Authentic leadership tends to improveemployee job satisfaction.

H2.1 Authentic leadership tends to encourage communication between nursing personnel and patients.

H2.2. In turn, it is expected that higher levels of communication between nursing personnel and patients will improve the perceived quality of care by patients

H3.1. Authentic leadership tends to mitigate work-life disruption and interference

H3.2. In turn, mitigated work-life interference tends to enhance job satisfaction

H4. Higher levels of employee job satisfaction tend to lead to higher perceived quality of healthcare service by patients

II. METHODS AND MATERIAL

Study Design

This study involves human participants and was approved by Papageorgiou General Hospital Ethics Committee. Number. 118/17-2-2021

The study hypothesizesthat authentic leadership, may directly influence job satisfaction (hypothesis 1). Moreover, authentic leadership positively influences communication between nursing personnel and patients (hypothesis 2.1), which in turn improves quality of care (hypothesis 2.2). Additionally, authentic leadership tends to mitigate work-life disruption and interference (hypothesis 3.1). Furthermore, lower levels of work-life interference tend to enhance employee job satisfaction thus improving healthcare quality(hypothesis 3.2 and 4). The structural model, encompassing and testing all the above-mentioned hypotheses, is illustrated in Figure1.

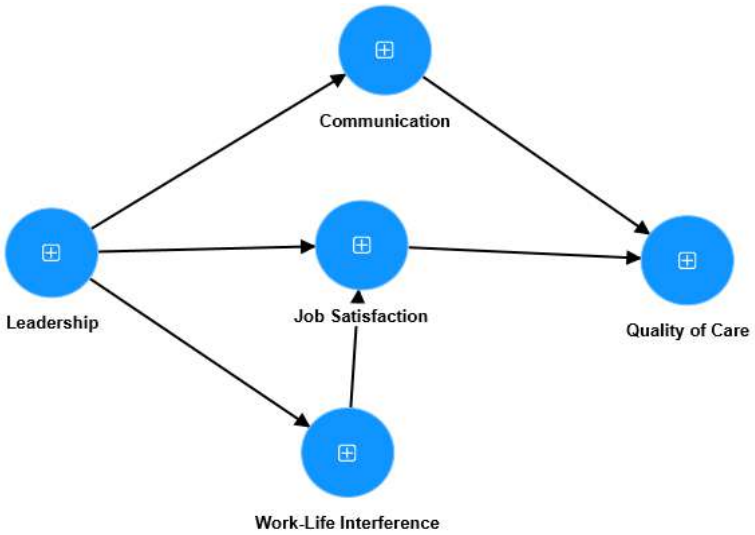

Figure 1. The structural model

Instrument and participants

The empirical study used a survey covering the nursing personnel at the General Hospital Papageorgiou, located in Northern Greece. The survey used as an instrument a questionnaire encompassing all the measures used in the empirical model such as Authentic leadership, Work-life interference, Communication, Job Satisfaction and Quality of Healthcare. Participation of the nursing personnel in the surveys was voluntary.

Anonymity and confidentiality were emphasized to all participants with a cover letter accompanying the questionnaire. First, a pilot survey was conducted delivering the questionnaire to a limited number of healthcare professionals checking the clarity of the instrument. Next, a semi-structured interview was conducted in each ward to ensure that the all the items of the questionnaire were comprehensible to each single member of the nursing personnel of the hospital. In each ward a staff member was designated to voluntarily collect the completed questionnaires. Thus the empirical research was based on 530 usable questionnaires. The participation rate in the survey was high reaching 81%. Participants' mean age was 42 years,averaging 16 years of work experience. The majority of the respondents were female (83,6%). Also 62% of the survey participants graduated from a university nursing school and 12% held a master's degree in health sciences.

Ethical considerations: The study protocol and the research questionnaire were reviewed and approved by the hospital ethics committee. (Study approval no 339-19/02/2021)

Measures of the instrument

For the model's variable*Authentic Leadership*,the study adopted the authentic leadership questionnaire (Gardner, et al., 2005) which consists of 16 items that measure four dimensions of authentic leadership behavior: self-awareness, moral-ethical perspective, balance processing, and transparency. Participants rate items on a 5-point Likert scale from 1 to 5 (1=completely disagree and 5 = completely agree). The questionnaire had two versions, one for leaders to answer about themselves (self-report) and another for employees to rate their leaders. Both questionnaires were distributed and analysed separately to detect discrepancies between self-reporting and nurses' perception of their leaders.

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*Work-life interference*was measured using the Work-life conflict questionnaire (Fisher, et al., 2009). The questionnaire consists of 24 items rated on 5 level scale ranging from 1 to 5 (1=not at all and 5=almost all the time). We used this questionnaire because it measures work-no work interference and enhancement for all workers regardless of their marital or family status. Family is an important part of life, but workers may hold other important no work roles and responsibilities that impact their experiences of work-no work interference. The questionnaire consists of positive and negative answers that they are reverse scored.

Patient quality of care was measured using the Patient Satisfaction with Nursing Care Quality Questionnaire (PSNCQQ) (Schaufeli and Bakker, 2004). The PSNCQQ has 19 items rated on a 5-point Likert scale ranging from 1 to 5 (1=poor and 5=excellent). For general results the scores of all items can be summed and averaged to yield a single value for each patient. A sample of 200 patients, answered the questionnaire. The patients interviewed were not exclusively Covid-19 patients, but it was a random sample of 100 Covid and 100 non-Covid patients. The idea was to detect inequalities of care between Covid-19 and non-Covid patients.

Statistical Analysis

For estimating our model and testing our four hypotheses, we used the Smart Partial Least Squares-Structural

Equation Modelling (PLS-SEM) software version 3.2 (Smart PLS 3.2.). PLS-SEM is a statistical method that is usually applied when the model is complex and involves numerous latent variables, including mediating and moderating variables (Laschinger, et al., 2005; Hair, et al., 2011). One of the advantages of PLS-SEM is that estimates the measurement model which assess the association between latent variables and their indicators and its structural constituent which measures the causal relationships among latent variables verifying or not the theoretical hypotheses (Hair, et al., 2011). In assessing our measurement model, we employ two main criteria: construct reliability and discriminant validity(Hair, et al., 2011).

1.1 Estimating the model

Before estimating the structural model, we had to apply Exploratory Factor Analysis (EFA) to evaluate the measurement model. In Table 1,we present the results of construct reliability indicated by Cronbach's Alpha. This measure indicates how well questionnaires data represent the model's variables. Cronbach's alpha estimations for the subscales of the latent variables exceeded the critical value of 0.7. Therefore, the statistical criteria for construct reliability and validity are satisfied in our model.

Table 1. Cronbach's alpha criterion for Construct Reliability and Validity

	Cronbach's alpha
Communication	0.827
Leadership	0.9
Work-Life Interference	0.879

In table 2, the Fornell-Larcker test for Discriminant Validity is presented demonstrating the independence of model's variables from each other. The diagonal elements are the square root of average variant extracted (AVE).

Table 2. Fornell-Larcker criterion for Discriminant Validity

	Communi	Job Satisfa	Leadershi	Quality of	W_L_Inter
Communi	0.649				
Job Satisfa	0.21	1			
Leadershi	0.202	0.291	0.71		
Quality of	0.316	0.237	0.186	1	
Work-Life	-0.248	-0.388	-0.251	-0.122	0.67

1.2 Path coefficients and hypotheses testing

To test the validity of our four research hypotheses we ran the structural model with a bootstrapping procedure that used 5,000 randomly drawn samples with replacement. In Figure 2 we present the estimated path coefficients and the corresponding P-values. More particularly, in Figure 2we display the estimations of our structural model.Positive or negative sings of path coefficients (see the arrows among the circled variables in Figure 2) demonstrate the positive or negative influence between variables. For example, Authentic Leadership

is hypothesized to have a positive influence on Job Satisfaction and a mitigating effect on Work-Life Interference,which in turn is expected to have a negative effect on Job Satisfaction.

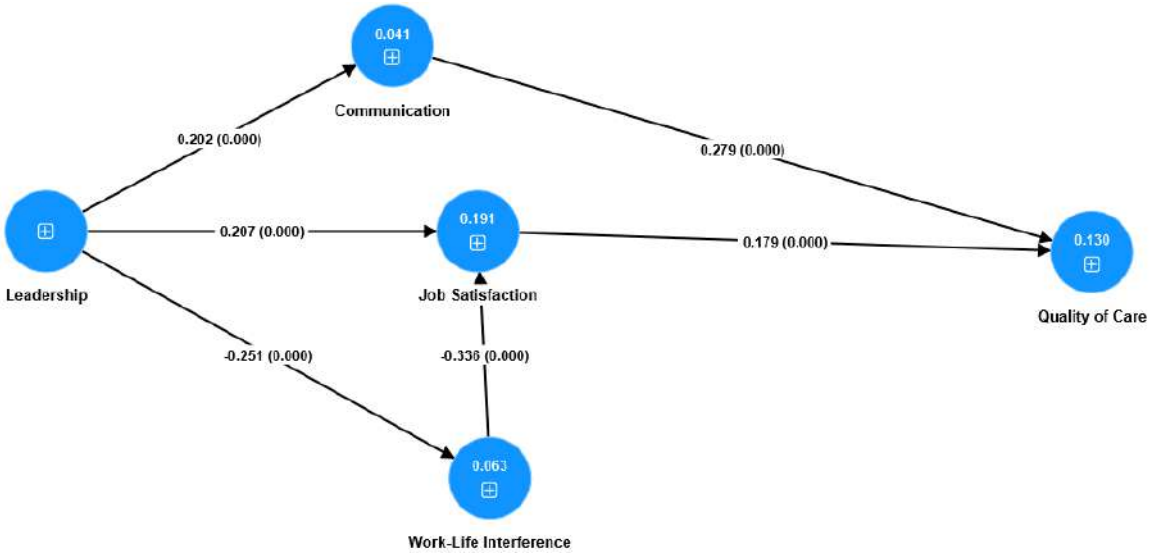

Figure 2. Measuring the Structural Model

All the path coefficients of the structural model have the hypothesized sign. Relatively high path coefficients and corresponding low P-values (in parentheses, Figure 2) are observed. Based on these results, we observe that all the research hypotheses are supported.

III.RESULTS AND DISCUSSION

The results of our model estimation show the mechanism through which authentic leadership influenced nursing personnel's quality of healthcare services during the challenging period of the Covid-19 pandemic. The model showed that effective leadership is important in mitigating Work-Life interference. Fortunately, and quite expectedly, leadership seems to suppress Work-Life for overloaded nursing personnel. Also, leadership tends to support communication between professionals and patients. These two influences, in turn, tend to increase the quality of healthcare services, even under healthcare crisis conditions, like those in the Covid-19 pandemic.

More specifically, according to the estimation of our model (Figure 2), one observes that the impact of authentic leadership on nurses' job satisfaction is mediated through work-life interference. This model estimation sheds light on the mechanism through which quality leadership mitigates nursing personnel's Work-Life interference, a very important development indeed for the quality of healthcare services under the pandemic pressing working conditions. Precisely, according to our model authentic leadership seems to influence positively communication at the workplace enhancing the quality of care. Finally, higher levels of job satisfaction tend to improve patients' quality of care.

This means that the main impact of leadership on employee performance is mediated though its positive effect on communication and work-life interferences, indicative of our model's significance as a managerial tool in managing human resources in healthcare services. An additional practical implication of our model is that healthcare organizations should focus on employing and promoting the most qualified people for team leading positions. Indeed, the preceding discussion highlights the vital role of the team leaders who have the responsibility of empowering healthcare personnel and facilitating their work-life arrangements, benefiting thus patients' healthcare quality.

IV. CONCLUSION AND LIMITATIONS

Conclusion

Our results emphasize the positive effect of authentic leadership through communication and work-life balance to enhance nursing personnel's job satisfaction and provide evidence of an increase in patients' perception of quality of care. Our study also demonstrates that during difficult times, like the pandemic, if leaders implement supportive measures on work-life balance and communication skills in the work they can lead their associates to high levels of professional efficacy. On the other hand, leaders should be aware of their tendency to overestimate their leadership abilities.

Study limitations

There are some limitations in our study. First, it is a single hospital study and not a national survey. So there is a need the healthcare industry to be examined further, across the country and across borders. Therefore, it is not wise to generalize about the study's results. Second, this present study is cross-sectional in nature, since the data was collected at a one time-point, so the directions of the causality among variables cannot be examined. However, it has been issued that "a lot of good work can still be done cross-sectionally, as in the exploration of different theories of employee well-being, especially when a strong theory-driven model is tested through structural equation modelling" (Boxall, Guthrie and Paauwe, 2016, p. 109).

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A Hybrid GAN-ANN-Based Model for Diabetes Prediction

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ABSTRACT

Millions of people around the globe have diabetes, which is a widespread chronic condition. It occurs when the body cannot properly process glucose, the primary energy source for the body's cells. This can lead to various health complications, including cardiovascular diseases, kidney damage, and blindness. Therefore, a predictive tool is urgently needed to help physicians detect the disease early and suggest the necessary lifestyle changes to halt its progression. Artificial intelligence technologies, such as machine and deep learning, have emerged as a means to reduce human effort and increase automation with minimal errors. This paper proposes a diabetes detection and prediction system based on deep learning techniques. Our approach employs Generative Adversarial Networks (GAN) to augment and impute data, while Artificial Neural Networks (ANN) are used for data training and decision-making. Experimental results on the Pima dataset demonstrate promising prediction outcomes compared to eight other machine learning techniques.

Keywords: Artificial Intelligence, Deep Learning, GAN, ANN, Machine Learning, Diabetes Detection, Diabetes Prediction.

I. INTRODUCTION

The number of chronic patients worldwide, particularly those with diabetes, has significantly risen. Unfortunately, underdeveloped countries struggle with insufficient infrastructure to handle the growing demand, causing private health services to become increasingly costly. While diabetes is not a fatal disease, severe issues in organs like the kidneys, eyes, and peripheral organs might result from it.

Diabetes can be divided into two main types: (i) Type 1 diabetes, commonly known as insulin-dependent diabetes, is frequently discovered in adolescents and young children. It happens due to the immune system attacking and destroying insulin-producing cells, which stops all insulin synthesis completely. As a result, patients require daily insulin injections or an insulin pump. Failure to manage Type 1 diabetes correctly can result in complications such as neuropathy, nephropathy, retinopathy, and cardiovascular disease.

(ii) Diabetes type 2 is also called non-insulin-dependent diabetes. This type of diabetes is the most prevalent. It is usually diagnosed in older adults but can also occur in younger individuals. This type occurs when the body still produces insulin, but it is either not enough or the body is unable to use it effectively. The majority of the time, oral medications and lifestyle modifications (such as diet and exercise) help treat type 2 diabetes, although insulin may occasionally be required as well. If it is not adequately treated, it can have the same consequences as type 1 diabetes.

There is a variation of diabetes that occurs during pregnancy named gestational diabetes mellitus (GDM). Although it usually goes away after birth, both the mother and the child are at an increased risk of having type 2 diabetes in the future. During pregnancy, the body becomes less sensitive to insulin in GDM, which raises blood sugar levels.

As they say, "Prevention is better than cure." It is important to note that proper management, including regular monitoring and treatment, can help prevent or delay the onset of complications in all forms of diabetes. The prediction of diabetes has been examined in several works [4], [8], [13], [17], [20], [32]. These studies have considered various patient data elements, such as molecular trait variability, environmental factors, electronic health records (EHRs), and way of life. The developed models are based on historical experience and claims using health conditions and vital signs. The most commonly used dataset is the Pima Indians Diabetes Database [19], which consists of 768 samples, 268 individuals who are diagnosed with the condition, and eight independent variables that are used to determine if the patient has diabetes or not. Classes in this dataset are underrepresented, and when analyzing a medical dataset where the proportion of healthy patients is much higher than that of affected patients, classification algorithms may struggle to identify the minority classes because even if they classify every minority class incorrectly, the program will still have a low error rate [10]. Data augmentation is a possible solution to tackle this problem, which consists of increasing the representation of the minority class and helping to avoid overfitting.

With considerable data flows, it is now possible to apply algorithms that give automatic and more accurate answers to different medical problems. Despite the promising results obtained using machine or/and deep learning (ML/DL) approaches. In order to improve patient outcomes and reduce the burden of diabetes on healthcare systems, this work proposes an accurate and helpful system allowing from a set of clinical data to detect whether the person has diabetes or to predict whether he/she is in the pre-diabetes phase.

Our method stands out by offering a complete solution that not only increases the accuracy of classification but also tackles the common problems of unequal class distribution in healthcare data. It provides a more effective approach for use in real-life healthcare situations. In this work, our contributions are:

- We used Generative Adversarial Networks (GANs) for data imputation to minimize the impact of missed data.
- We used Artificial Neural Networks (ANNs) for data training and decision-making.
- We evaluated the suggested method's effectiveness compared to eight machine learning techniques, including Naive Bayes, artificial neural networks, support vector machines, and random forests.

The remaining sections of the paper are structured as follows: Section 2 evaluates several comparable publications, Section 3 provides the study methods, Section 4 specifies the assessment, Section 5 discusses the collected results, and Section 6 ends the paper and offers potential areas for future work.

II. Related Work

The identification of diabetes using machine learning and deep learning has been the subject of numerous relevant publications in the literature.

A. Machine Learning Approaches

Using machine learning algorithms to predict diabetes has been an important subject in research for more than a decade. Numerous machine learning techniques have been employed to forecast diabetes, such as decision trees [6], [7], [25], Random Forest [3], [21], [24], [27], k-Nearest Neighbors (k-NN) [29], neural networks [9],

[30], and Support Vector Machine (SVM) [31], [37]. For instance, [31] explored the use of SVM models to predict the onset of type 2 diabetes based on various clinical and demographic features. The outcomes demonstrated that the SVM models had a high degree of accuracy in predicting the onset of type 2 diabetes. The authors reported an overall accuracy of 94.5% over PIMA for their SVM model.

For predicting diabetes, hybrid approaches that incorporate several machine learning algorithms have also been explored. By combining these methods, the effectiveness of individual models is increased while taking advantage of the advantages of various algorithms. For instance, in [36] a hybrid model of k-means and decision trees has been proposed. Also, [38] used a combination of random forest and support vector machine (SVM) algorithms to improve the prediction performance of diabetes.

Additionally, the study of [18] examined the performance of different machine learning algorithms on the Pima Indian dataset, including decision trees, k-NN, logistic regression, and SVM. They discovered that the SVM method has the highest level of precision. While [16] employed mutual information as a feature selection strategy and machine learning classification techniques, such as decision tree, SVM, Random Forest, Logistic Regression, K-NN, and various ensemble techniques, to ascertain which algorithm delivers the best prediction results. With 81% accuracy, the suggested system delivered the best result in the XGBoost classifier.

More recently, [33] using Decision Tree, SVM, and Naive Bayes, they created a model that successfully predicts diabetes in a patient group. Additionally, [2] combined PIMA with logistic regression, XGBoost, gradient boosting, decision trees, ExtraTrees, random forest, and the light gradient boosting machine (LGBM). According to the results of these classifiers, the LGBM classifier has the highest accuracy (95.20%), when compared to the other algorithms. An overview of the state of the art in using machine learning to predict diabetes mellitus can be found in [5], [40] and [41].

B. Deep Learning Approach

Artificial neural networks are the foundation of the machine learning subfield known as deep learning. It has been increasingly used for diabetes prediction in recent years. These models have been shown to be effective in handling high-dimensional and non-linear data and have achieved good performance on various datasets. Some works that have used Convolutional Neural Networks (CNNs) [11], Recurrent Neural Networks (RNNs) [39], Generative Adversarial Networks (GANs) [22], and Deep Belief Networks (DBNs) [28] have shown their effectiveness in identifying signs of diabetic retinopathy, analyzing time series data and generating synthetic data, and analyzing various features such as age, body mass index, and blood pressure. For instance, [12] used CNNs for diabetes prediction by analyzing images of the retina to identify signs of diabetic retinopathy. Additionally, [35] used a modified version of the generative adversarial network, where the generator computed Blood glucose (BG) predictions using a recurrent neural network with gated recurrent units and the discriminator used a one-dimensional convolutional neural network to differentiate between the predictive and real BG values.

More recently, DBNs have been used by [1] for solving regression problems in detecting diabetes by analyzing various features such as blood pressure, body mass index, and age. Furthermore, [26] used vote ensemble feature selection and DBNs for diabetes early detection in a Bangladeshi online library of prediagnosed patients' answers. Ref. [14], [23], and [34] provide an overview of the state of the art in applying deep learning to predict diabetes mellitus.

As far as we are aware, no research has combined artificial neural networks (ANNs) and generative adversarial networks (GANs) to predict diabetes.

III. Research Methodology

This section delineates the research methodology employed in this study.

A. *Dataset*

The Pima Indians diabetes database is a collection of medical data on Pima Indian women who live close to Phoenix, Arizona and who underwent World Health Organization-required diabetes testing. The dataset includes 8 features and 768 instances, including:

- Pregnancies: The total number of pregnancies;
- Blood Pressure: Diastolic blood pressure (mm Hg);
- Plasma Glucose Concentration: 2-hour oral glucose tolerance test;
- Triceps skin fold thickness in millimetres;
- Body mass index is calculated as follows: weight in kg/(height in m)2;
- Insulin: 2-hour serum insulin (mu U/ml);
- BMI: body mass index;
- DiabetesPedigreeFunction: diabetes pedigree function;
- Age: Age (years); Class variable: 0 or 1;
- Outcome: Age (years);

This dataset, which has 268 samples classified as diabetes and 500 as non-diabetic, is frequently used for binary classification issues.

The Pima Indian dataset is often regarded as biased due to its imbalanced class distribution, focusing on a specific ethnic group (Pima Indians). Also, the dataset is often criticized for its imbalanced class distribution, meaning that there are disproportionately more instances of individuals with diabetes compared to those without. This imbalance can pose challenges for machine learning models, as they might exhibit a bias towards predicting the majority class, potentially leading to less accurate predictions for the minority class. Addressing the imbalance in the dataset and ensuring accurate model evaluation will be discussed in the following sections, employing Generative Adversarial Networks (GAN) for enhanced data generation and improved representation of minority classes.

B. *Data imputation with Generative Adversarial Networks*

A generative modeling strategy called generative adversarial networks, or GANs [15], was suggested by Goodfellow et al. in 2014. The foundation of GANs is a game theoretic scenario where the generating network faces off against an opponent.

A generative model is trained in this stage to deceive a feedforward classifier. The feedforward classifier should recognize all samples from the generative model as false, whereas all samples from the training set

should be recognized as real. Any organized pattern the feedforward network may identify is highly prominent in this approach. The discriminator and the generator are the two primary parts of a GAN.

The generator is a neural network that uses random noise input to generate fresh data samples that resemble training data; its network directly generates samples using equation (1), which maps noise variable z to data space x and defines a stochastic process to simulate data x.

$$x=g(z;\theta(g)) \quad (1)$$

Our model has three layers, with the 'ReLU' function activating two of them. Then, the linear function will trigger the output layer, and its dimension will be the same as the dimension of the dataset (9 columns).

The discriminator is also a neural network that takes in a sample and produces a probability that the sample is real. It then compares this probability to a threshold value (usually 0.5) to make its decision. It tries to distinguish between the generated samples and the real samples emitting a probability value given by $d(x;\theta(d))$. This indicates the likelihood that x represents an authentic training sample, as opposed to a synthetic sample generated by the model. Our discriminator is a sequential model with three dense layers. The function activates the first two layers, while the 'sigmoid' function activates the output layer since it will determine if the input samples are true or false. We produced 1602 lines, comprising 602 lines of real data and 1000 lines of generated data.

C. *Diabetes prediction using ANN*

We employed neural networks and a sequential model with three layers for data training. The rectified linear unit (ReLU) function operates on the first two levels to activate them. 1000 neurons make up the first layer, while 500 neutrons make up the second. The sigmoid function activates the output layer because we have a 0 or 1 output. A mathematical function called the sigmoid function converts any input value to a number between 0 and 1. Equation 2 defines it.

$$F(x) = 1 / (1 + e^{(-x)}) \quad (2)$$

The output of the sigmoid function is also known as the "squashing" function, as it compresses the output of a neuron to the range between 0 and 1. The sigmoid function is often used as the activation function in the output layer of a binary classification neural network, as it can be interpreted as the probability of the positive class. It was employed to choose the neural network's output. It converts the outcomes to a number between 0 and 1 or -1 and 1.

On the other hand, the ReLU function is a straightforward mathematical formula that converts every input value to the maximum of that value and zero. Eq. (3) provides a definition for it.

$$F(x) = \max(0, x) \quad (3)$$

The ReLU function is particularly useful in deep neural networks as it can improve the training time and the model's performance by solving the vanishing gradient problem. The ReLU function is often used as the activation function in the hidden layers of neural networks, as it is computationally efficient and does not saturate for positive input values. Figure 1 illustrates a flowchart detailing the proposed system.

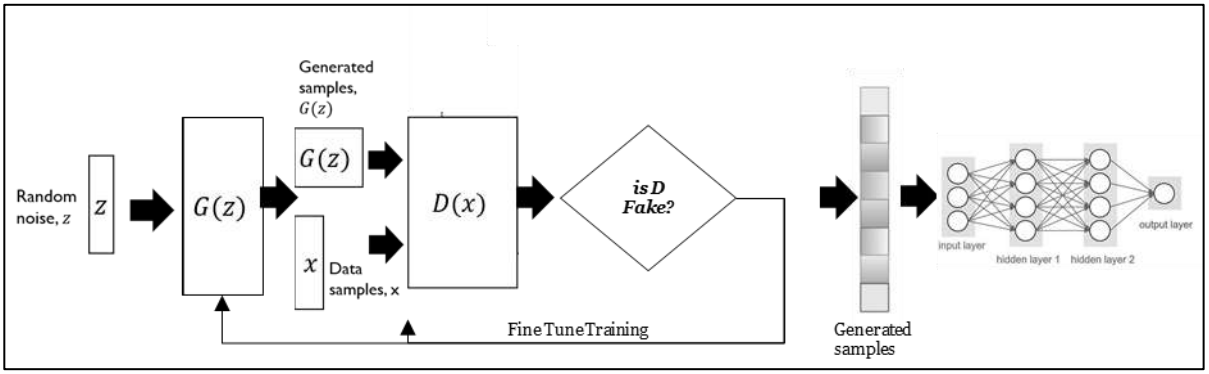

Fig. 1 The proposed GAN-ANN Approach

IV. Results and Discussion

The proposed approach sought to address the issue of imbalanced datasets within the biomedical domain. In this phase, we compared the GAN-ANN model with eight alternative machine learning methods, encompassing Naive Bayes, AdaBoost, and ANN, along with Decision Trees, K Nearest Neighbours (KNN), Quadratic Discriminant Analysis (QDA), Random Forest, and Support Vector Machine (SVM). Indeed, these algorithms are commonly used and generally robust for binary classification tasks. However, their performance may vary based on the dataset's characteristics and the specific requirements of the problem at hand, which the achieved results can prove.

The assessment of precision, recall, f1-score, and accuracy in Equations (4–7) was employed to evaluate performance. Table 1 and Figure 2 compare eight machine learning algorithms and the GAN-ANN-based technique.

$$\text{Precision}=TP/(TP+FP) \quad (4)$$

$$\text{Recall} =TP/(TP+FN) \quad (5)$$

$$\text{F1-score}=TP/(TP+1/2(FP+FN)) \quad (6)$$

$$\text{Accuracy}=(TP+TN)/(TP+TN+FP+FN) \quad (7)$$

Such as:

- TP stands for true positives.
- FP stands for the number of false positives.
- TN stands for the number of true negatives.
- FN stands for false negatives.

TABLE I. COMPARISON OF THE GAN-ANN-BASED APPROACH AND EIGHT MACHINE LEARNING ALGORITHMS

Approaches	+/-	Precision	Recall	F1-score	Accuracy
GAN-ANN	0	0.94	0.96	0.95	0.94
	1	0.95	0.93	0.94	
Decision tree	0	0.84	0.77	0.80	0.75
	1	0.63	0.73	0.68	
KNN	0	0.77	0.82	0.79	0.73

	1	0.63	0.56	0.60	
QDA	0	0.84	0.82	0.83	0.78
	1	0.68	0.71	0.70	
Random Forest	0	0.81	0.81	0.81	0.75
	1	0.65	0.65	0.65	
SVM	0	0.78	0.88	0.83	0.77
	1	0.72	0.56	0.63	
Naïve bayes	0	0.83	0.80	0.81	0.77
	1	0.66	0.71	0.68	
ANN	0	0.70	0.92	0.79	0.69
	1	0.67	0.29	0.41	
AdaBoost	0	0.80	0.79	0.79	0.73
	1	0.62	0.64	0.63	

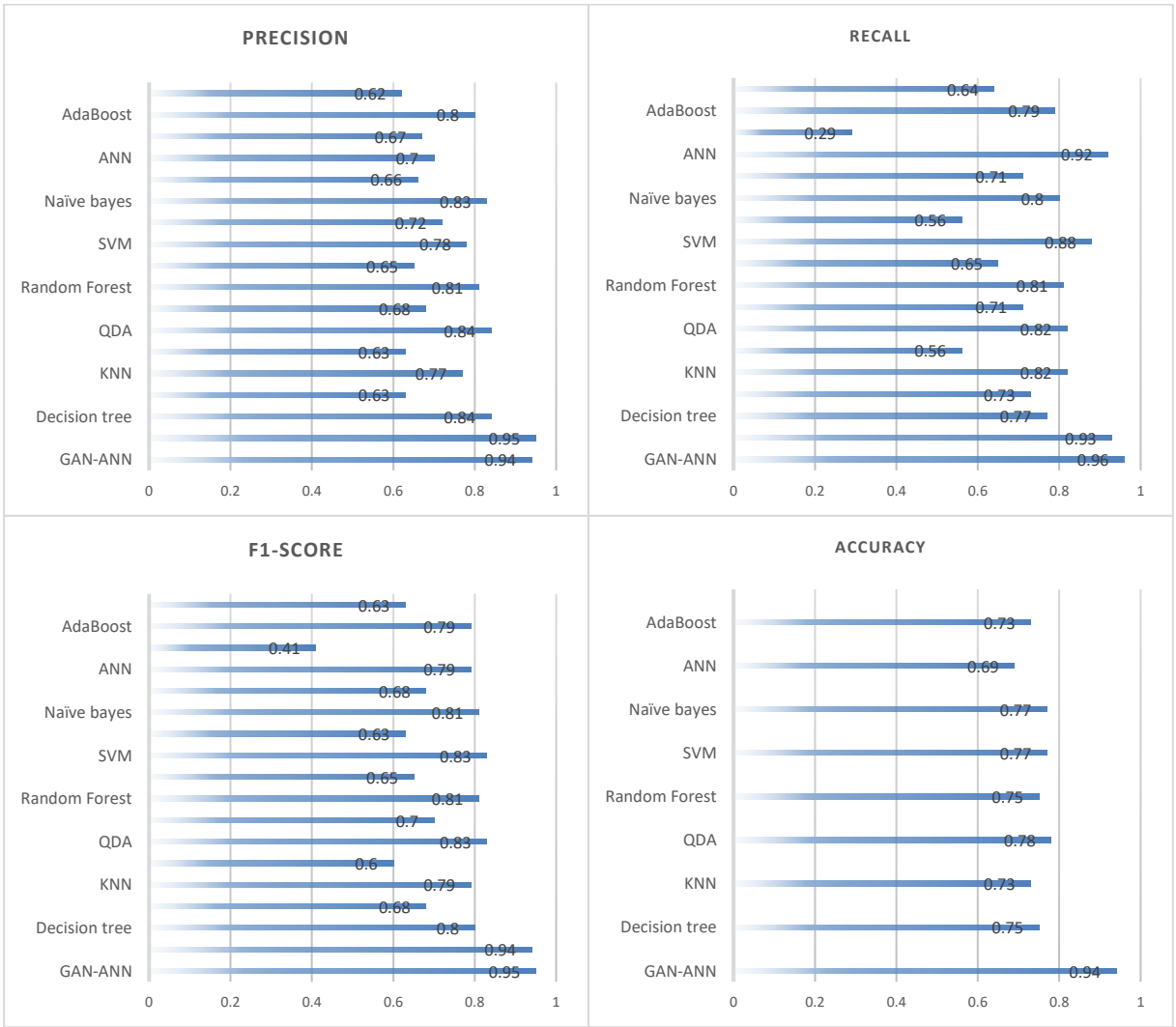

Fig. 2 Evaluating the GAN-ANN-based Approach Against Eight Machine Learning Algorithms

Based on the results, the developed GAN-ANN model exhibited notable performance metrics, including an accuracy of 94%, precision of 95%, recall of 93%, and an f1-score of 95% for predicting diabetes. Significantly, the model outperformed the eight alternative machine learning techniques regarding precision, recall, f1-score, and overall accuracy.

All machine learning achieved accuracy values are very close to each other. This suggests that the performance of the compared models is very similar and that there is little difference in their accuracies. Generally, SVM is often adequate for binary classification tasks; in our case, it achieved an accuracy 0.77. Adaboost and Naïve Bayes rely on probabilities to make predictions. In this case, Naïve Bayes outperformed AdaBoost with an accuracy of 0.77 and 0.73, respectively.

Meanwhile, QDA is a generative model that uses Bayes' theorem to compute the posterior probability of each class given an input. The algorithm gave the best accuracy value among the eight comparison algorithms; it achieved 0.78. KNN and decision trees gave low accuracy values, 0.73 and 0.75, respectively. Decision trees can be sensitive to even minor changes in the data, resulting in various tree architectures and forecasts. The tree may become weaker and more challenging to understand as a result. At the same time, KNN can be sensitive to the number of neighbors (k) selected. While a significant value of k can result in underfitting and subpar performance, a small value of k can result in overfitting. When the training set is small, artificial neural networks (ANNs) are prone to overfitting the training data. This can lead to poor performance when applied to new, untested data, as reflected in its lowest accuracy. However, In the GAN-ANN model, GANs could generate realistic data even when there was noise or missing information. This capability improved the ability of the ANN classifier to handle input data that is noisy or incomplete. By combining the strengths of both networks, we enhanced the accuracy and robustness of the classification task, leading to improved overall performance.

Our approach has practical implications that span from advancing early-stage diagnostics and treatment to influencing policies and ultimately elevating the overall quality of patient care while mitigating complications.

V. CONCLUSION

The study utilized a hybrid GAN-ANN approach to predict diabetes in an Indian population, demonstrating superior performance compared to eight other machine learning algorithms with a 94% accuracy. Despite this achievement, the study's limitations include a relatively small sample size, even after data imputation, potentially limiting the generalizability of the findings to other populations. Furthermore, the study overlooked additional diabetes-associated variables, such as primary predictor characteristics, family history, and lifestyle. To enhance future research, there will be a concerted effort to gather more comprehensive and representative datasets spanning a wider range of ethnicities, socio-economic backgrounds, and health conditions. Additionally, addressing biases in biomedical datasets will be a crucial focus, emphasizing developing and implementing robust strategies, including using fairness-aware machine learning algorithms, to ensure equitable representation across diverse demographic groups.

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Deep Learning-Based Handwriting Digits Classification

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ABSTRACT

The digitization and storage of information in various fields have become increasingly crucial in recent times. In particular, there is a significant demand for converting printed, handwritten, or image data into an editable format. Several issues arise during the digitization process and the recognition of such information. Various technological approaches have been necessary to extract and store textual data from image files. Optical Character Recognition (OCR), a widely recognized technology, converts text from scanned documents or images into digital text, which can be edited and utilized for storage. Nonetheless, issues arise because of character characteristics, the deficit of spacing, axis shifts in the text, and image quality within scanned documents, particularly those that are handwritten, leading to challenges. The use of artificial intelligence-based techniques has improved the accuracy of character recognition. Convolutional Neural Networks (CNNs) are the preferred technique for computer vision problems. In this study, handwritten digits were collected from students in the Turkish National Education System and pre-processed before being used to create a labeled database. A CNN was used to classify the digits. The promising results obtained from the experimental studies demonstrate the efficacy of this approach.

Keywords: Classification, Handwriting Digits, Deep Learning, Convolutional Neural Networks, Optical Character Recognition

I. INTRODUCTION

Optical Character Recognition (OCR) involves identifying and transforming printed and handwritten characters into a digital format, allowing them to be edited and stored. This conversion facilitates convenient searchability and access to the text on digital platforms. OCR presents a demanding discipline that has gained considerable interest from researchers in fields such as pattern recognition, artificial intelligence, and machine vision. The ability to identify characters in an image that includes text and convert them into digital format is crucial in various sectors, including businesses, libraries, and government agencies, as it streamlines their operations [1].

There are two main categories of OCR: Printed Character Recognition (PCR) and Handwritten Character Recognition (HCR) [2]. Due to using a particular font in PCR, identifying characters is comparatively simpler

than in HCR. The complexity of the font used in HCR makes it difficult to distinguish and isolate individual letters. There are two subcategories of HCR: Online Handwritten Character Recognition and Offline Handwritten Character Recognition. [3]. In online recognition, handwritten characters are easier to recognize, and the accuracy rate is higher because users' pen strokes can be tracked as they write. However, offline handwriting recognition involves writing the characters in documents. With offline handwriting recognition, even if people use the same language and alphabet, their handwriting will be different from each other, making recognition a serious challenge for researchers. It is well known that differences in a person's handwriting can even be considered biometric data [4]. Offline, images are usually captured using cameras or optical readers, and character recognition is often performed using image processing and artificial intelligence-based approaches.

In the last decade, as technology has advanced at a rapid pace, there have been many studies of HCR using artificial intelligence techniques [5]. The K-Nearest Neighbours (k-NN) approach is one of the most common approaches in various HCR studies. The k-NN is a lazy learning method in which the model stores all training data for prediction instead of performing a training process. Because it is simple and effective, it is often used in classification and regression processes. Puja Romulus et al. developed an application that converts an image of Batak symbols into Latin characters. In this application, the k-NN approach was used and a classification success of 96% was achieved [6]. Inkeaw et al. used three different feature extraction methods for Lanna Dharma HCR and used k-NN as a classifier [7]. Support Vector Machine (SVM) is a successful machine-learning algorithm for solving complex problems with high-dimensional data. G Vamvakas et al. proposed an SVM-based approach for historical document recognition using k-NN and Radial Basis Function (RBF) for character database. Rajakumar et al. proposed an algorithm for Tamil font recognition and used SVM as a classifier to classify the fonts. They achieved 94% accuracy in their studies [8]. Artificial Neural Networks (ANN) is a machine learning algorithm created by modeling the operation of neural networks in the human brain. Many studies in the field of HCR have been carried out using ANN. Sandhya N et al. used the endpoint algorithm to reconstruct degraded Kannada characters and employed an ANN for Kannada character recognition. They achieved approximately 99% success using a single-layer feed-forward ANN. [9]. Paulose et al. used ANN as a classifier for Malayalam handwriting recognition [10]. CNNs are a type of artificial neural network that has been successful in computer vision applications, including image classification, object detection, and image segmentation. Hailin Lang et al. have also used CNNs. [11] for character position detection in Chinese historical documents, and by Reem Alaasam et al. [12] for recognition of Arabic handwriting.

There have also been studies on handwriting recognition in Turkish. In Taşdemir's study [13], a Turkish handwriting recognition system was set up. Since there were no suitable data sets for this system, they created an artificial data set. The system, which was trained with real and artificial data, increased the recognition rate of Turkish characters from 61% to 88% as a result of the test with 2041 words of real data. Kabakus and Erdogmus [14] proposed a new CNN-based Turkish handwriting letter recognition model for Turkish character recognition. They created a Turkish handwriting dataset consisting of 25,875 samples. The accuracy of the proposed model was calculated to be as high as 96.07%. This model was trained and evaluated on the EMNIST dataset and achieved an accuracy of 94.61%. Çapar et al. [15] prepared a dataset of 20,000 characters for their study on Turkish capital letters. In their study, Nearest Neighbour, Nearest Average Neighbour, Bayesian Second Order Classifier, Parzen Classifier, Size Dependent Negative LogLikelihood (SDNLL), and ANN were used. The best classification percentage was achieved by SDNLL. The best

classification result in their study is 93.6%. In their study, Vural et al. [16] presented an online handwriting recognition system for Turkish. They extracted different dynamic features from the handwriting data for each point captured using tablet PCs and used Hidden Markov Models (HMM) to train letter and word models. In their study, they achieved 94% success in recognizing handwritten words from a 1000-word dictionary.
In this study, a pangram sentence and 80 Turkish characters were collected from each of 8,000 secondary school students aged 10-18 in the Turkish National Education System, along with their gender and age information through an optical form. Basic pre-processing steps were taken to label all characters for training. The handwriting digits of students were then classified using a CNN, and the obtained results were subsequently discussed.

II. MATERIAL AND METHOD

This research aims to achieve accurate identification of handwritten numerals collected from secondary school students. Initially, optical forms were produced to gather the required information from the students and the students were asked to complete these forms correctly. The forms were supervised by teachers, pre-processed, fragmented, and tagged through Python coding. After the dataset was established, a CNN model was proposed for the categorization process. Elaborate details are presented in the subsequent subsections.

A. Creating a Dataset

The objective of this research is to produce a unique dataset comprising Turkish characters, numerical data, mathematical symbols as well as a pangram sentence. The dataset was carefully curated to ensure that each entry adheres to the guidelines and regulations of accurate data collection and analysis.
A total of 8000 A5 forms in the design depicted in Fig.1 were dispersed among students enrolled in schools situated in the central districts of Konya province. The students, under the guidance of their teachers, completed these forms. The aforementioned forms, filled out by middle and high school students residing in Konya's central districts, were recorded employing both naming and scanning the image in the optical reading device. In the optical coding section, students encoded information such as gender and age.

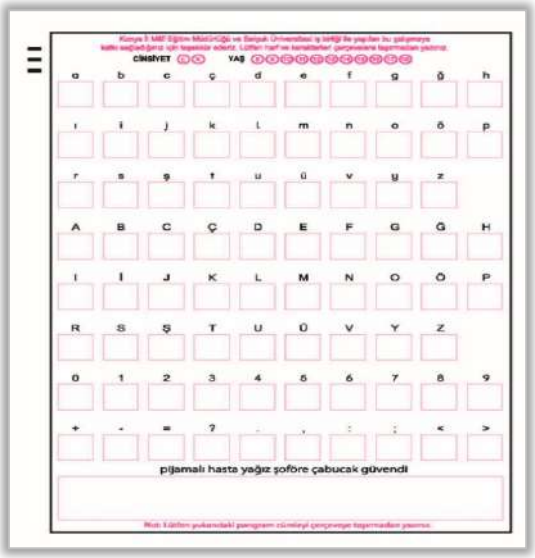

Figure 1: Empty A5 Form to gather the information.

To crop the images, we captured the outer frame and flattened it using Python image processing. All forms were aligned properly, and all characters were cut. The character cut-outs were arranged in directories as PNG pictures with dimensions of 108x108 pixels and a bit depth of 24. The images were labeled based on gender, age, and the student from whom the data was collected (Fig.2).

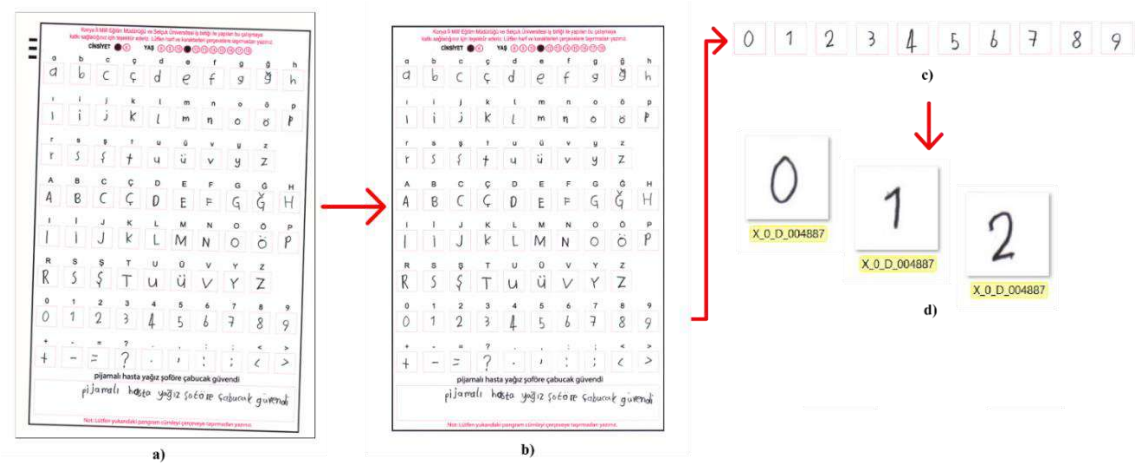

Figure 2: Image pre-processing stages, a) Scanned form, b) Flattered form, c) Digits cut from the form, d) Digit labeled according to age and gender

In addition, the number of cleaned data obtained from students depending on gender and age is detailed in Table 1. The forms obtained from 8000 students were analyzed in detail. However, some students were not included in the database due to incorrect filling of the optical forms. A total of 7470 forms were obtained from 3358 male and 4112 female students.

TABLE I

NUMBER OF DATA EXTRACTED AND CLEANED FROM STUDENTS BY GENDER AND AGE

Age	Male (0)	Female (1)
10(C)	128	146
11(D)	443	570
12(E)	571	596
13(F)	734	704
14(G)	536	586
15(H)	317	455
16(I)	227	416
17(J)	245	459
18(K)	157	180
Total	3358	4112
	7470	

B. Convolutional Neural Networks

CNNs are artificial neural networks commonly used in image processing, and their most basic components are learnable filters applied to input data. These filters in CNNs try to detect local patterns and features in the input images. CNNs typically use more than one convolutional layer. Convolution reduces feature maps in a

meaningful and spatial way. This reduces computational complexity and increases representativeness. These feature maps are subjected to non-linear activation functions to increase the level of training in the network. The first layers of the network reveal simple relationships, and subsequent layers reveal more complex and abstract relationships. This hierarchical and layered structure makes the learning process of CNNs successful. CNNs were chosen as the classifier in this study due to their successful results in image processing. The CNN network model used in the study is detailed in Fig. 3 below.

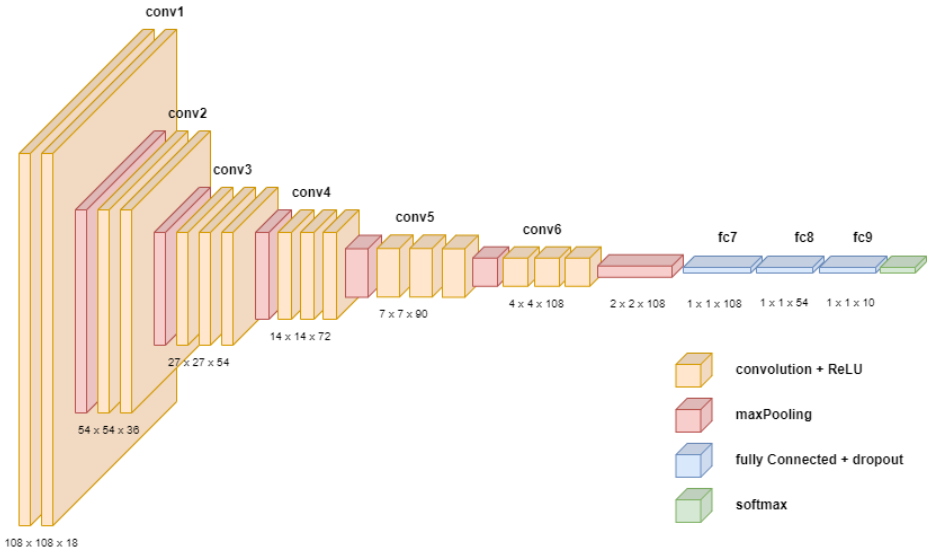

Figure 3: CNN model

The model comprises of nine stages, with the first six being convolutional and pooling layers, and the last three being fully connected layers. The initial stage, conv1, is a convolutional layer that uses a Rectified Linear Unit (ReLu) activation function.It accepts the preprocessed image as input, with a size of n*n=108*108. The convolution filter has a size of 3*3 with padding of 0 and stride of 2 and utilizes 18 filters. Following this convolution process, feature maps with a size of 18 x 108 x 108 are generated, which are then normalized through batch normalization with the batch Normalization Layer. This allows for simultaneous learning, leading to a reduction in training time and an improved model performance. ReLU activation is applied to each feature map, followed by applying the maximum pooling layer with a 2 x 2 pooling size, 0 fill, and 2 stride. This process results in obtaining feature maps of size 54 x 54 x 36. The conv1 process is repeated in the same way 5 more times. Here, a feature map of 1 x 1 x 108 is obtained by employing the maximum pooling layer. The fc7 initiates the fully connected layer process, which is the final and pivotal layer. It flattens the data, yielding a one-dimensional vector of 1 x 1 x 108. Next, the dropout layer is utilized to prevent the model from overlearning. Subsequently, the fc8 operation is employed again, producing a vector of 1 x 1 x 54. Finally, the fully connected layer is used again with the fc8 operation to obtain a vector of size 1 x 1 x 10. As a result, it is possible to classify the digits (0,1,2,3,4,4,5,5,6,7,8,9) in the images with accuracy.

III.EXPERIMENTAL RESULTS AND DISCUSSIONS

In this study, as detailed in prior sections, the dataset was initially acquired (completely incorrect instances within the existing classes have been deleted, reducing the total number of instances, which should normally

be 74700, to 74226) and subsequently, the CNN network model was utilized. For the CNN network, the training and test rates were determined as 80% and 20%, respectively. The CNN network was run for 60 epochs. The accuracy and loss graph of the CNN network is given below (Fig.4).

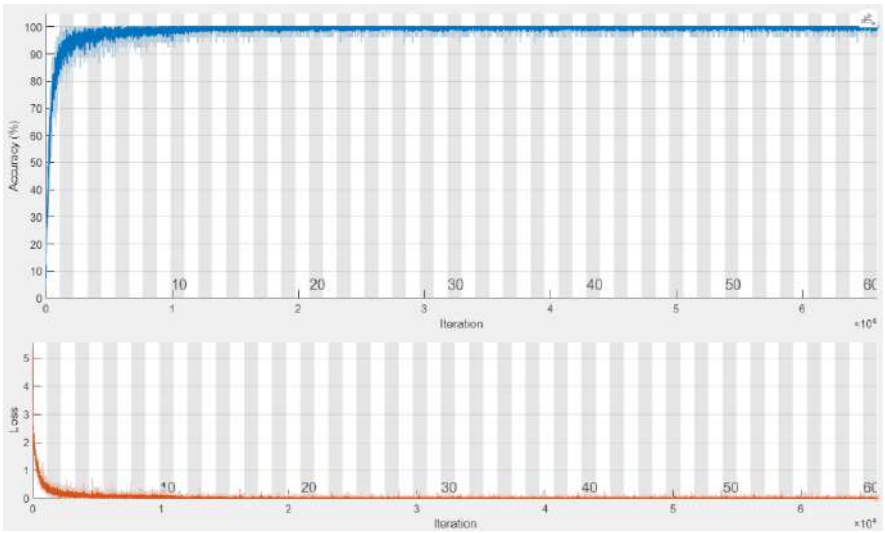

Figure 4: Training and Loss graphs

After completing the CNN network training process with a high success rate, the complexity matrix below illustrates the network's classification success with the test data (Fig.5). Upon analysis of the complexity matrix, it is evident that the test success rate for nearly all classes is 99%. Such results suggest the successful training of the network.

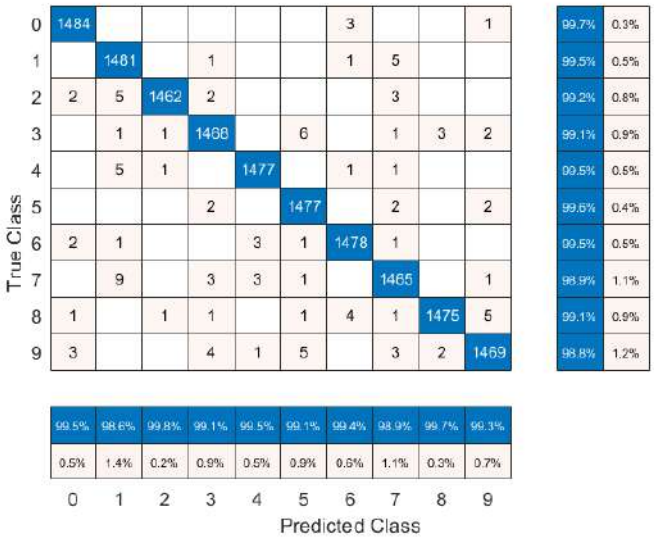

Figure 5: Confusion Matrix

The table presents the average values for accuracy, sensitivity, specificity, precision, recall, and Fscore achieved by a CNN model. The accuracy is particularly high, standing at 0.99854, which reflects the model's ability to categorize the images in the dataset accurately most of the time. The model's sensitivity is commendable, achieving a score of 0.99272, indicating its ability to accurately identify true positives.

Although the specificity score is slightly lower at 0.99919, it is still impressive, demonstrating the model's proficiency in correctly identifying true negatives.

The model's specificity is almost perfect at 0.99919, which is impressive. This indicates that the model is good at recognizing negative outcomes most of the time. With both precision and recall scores at 0.99272, the model identifies true positives and true negatives accurately. In addition, the Fscore of 0.99273 is excellent. This score considers both precision and recall measuring the model's ability to identify true positives and true negatives.

TABLE III

OBTAINED MEAN RESULTS

Accuracy	Sensitivity	Specificity	Precision	Recall	Fscore
0.99854	0.99272	0.99919	0.99274	0.99272	0.99273

The Receiver Operating Characteristic (ROC) curve is an important graph used to evaluate a classification result, showing the relationship between sensitivity and specificity (Fig.6). When the ROC curve is analyzed, it is seen that the desired result is ideally achieved in all classes.

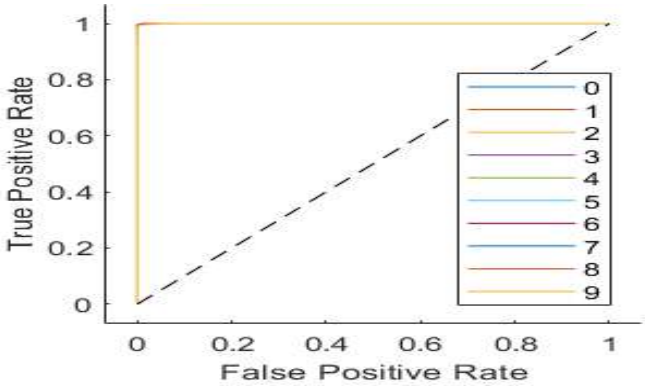

Figure 6: ROC Curve

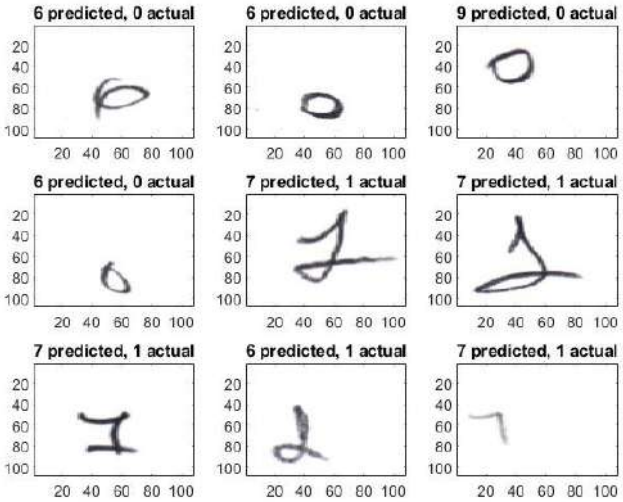

Figure 7: Incorrectly predicted examples.

As can be observed from the confusion matrix displayed in Figure 5, the trained CNN network has a remarkably low rate of incorrectly predicting samples during testing. Fig. 7 demonstrates some examples of incorrectly predicted samples, which are challenging to predict accurately by human eyes.

IV. CONCLUSION and FUTURE WORKS

It is of utmost importance that characters in printed, handwritten, and image files are accurately identified and saved in an editable format. Various approaches have been employed to tackle the challenges of recognizing handwritten characters, with notable success achieved through the application of machine learning algorithms in this area. Handwritings were collected in an organized form from students aged between 10-18. Subsequently, the forms underwent scanning and preprocessing to generate datasets. The study used a CNN as a classifier to identify the number of handwriting samples. CNN is a machine learning algorithm that has proven to be successful in image processing. The proposed CNN model achieved an accuracy of 99% in experimental studies.

The impressive application of CNNs in handwriting recognition offers exciting opportunities for future advances in this field. One notable possibility is the extension of datasets to include a variety of handwriting styles and cultural scripts, ultimately improving recognition accuracy. Furthermore, integrating CNN-based recognition into tasks such as the digitisation of historical manuscripts is a testament to its adaptability and preservation potential. Other potential applications of this technology could include rigorous testing for robustness, incorporation into educational grading systems, collaboration with industry for efficient document management, and exploration of AR/VR possibilities. It is clear that CNN has the potential to revolutionise handwriting recognition far beyond its immediate impact. In the future, it is hoped that the results obtained from this study can be used for automatic evaluation of students' answers in open-ended exams.

V. ACKNOWLEDGMENT

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Addressing a Complex Manufacturing Problem using Linear Programming Modelization and MOSA Metaheuristic

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ABSTRACT
In this paper, we delve into the unrelated parallel machines static scheduling problem, considering both renewable and non-renewable resource conditions, and accounting for the deterioration effect. The primary challenge lies in determining the optimal assignment of tasks to machines and the efficient allocation of resources, aiming to minimize both the makespan and the cost of non-renewable resources. To address these goals, we develop a mathematical programming model and apply a multi-objective simulated annealing algorithm to our problem. Our computational experiments encompass a range of instances, including small, medium, and large scenarios. The mathematical model proves effective for small instances with 8N2M, 10N3M, and 15N3M, providing solutions to the problem. Remarkably, for these instances, the MOSA approach achieves optimal solutions similar to those obtained by the solver but does so within a shorter computational timeframe.

Keywords—Metaheuristic, Linear Programing, Resources Cost, Unrelated Parallel Machine.

I. INTRODUCTION

Among the extensively studied scheduling problems, the parallel machine scheduling problem stands out. Numerous works have been published across various fields, including commercial, industrial, and academic domains. Scheduling problems related to parallel machines are typically classified into three categories: (1) identical parallel machines Pm, (2) uniform parallel machines Qm, and (3) unrelated parallel machines Rm.

The Unrelated Parallel Machine (UPM) scheduling problem involves the assignment of tasks to machines, where the processing time of a task varies between machines. A comprehensive overview of applications and reviews of UPM scheduling problems can be found in [1].

However, to execute a job, shape a product, or deliver a service, resources are essential. These resources fall into two main types: renewable resources and non-renewable resources.

- Renewable: when the resource, after completing the processing of a job, is then available for future jobs. This includes tools, labour, etc.
- Non-renewable: when the resource is consumed definitively in the process of a job, such as electricity, lubricant, etc. In the present research, both types of resources are considered: renewable and non-renewable resources.

Furthermore, in practical scenarios, the processing time is often variable and tends to fluctuate due to various factors such as the deterioration effect, learning effect, and the quantity of allocated resources.

The concept of the deterioration effect was initially introduced in scheduling problems by [2], and since then, it has garnered increasing attention in the literature on scheduling with changing processing times. This deterioration effect is particularly relevant in scheduling maintenance, responding to medical emergencies, or managing cleaning tasks, where delays in job handling can incur penalties.

The concept of flexible resource scheduling problems, where the processing time of a job varies based on the allocated resources, was initially introduced by [3]. Consequently, it is imperative to coordinate and optimize both job scheduling and resource allocation comprehensively to ensure the overall scheduling process is executed efficiently.

This contribution focuses on a scheduling problem where the processing time of a job is influenced by both its position on the machine and the quantity of additional resources allocated to it. Given that each job necessitates one or more resources, and considering that these resources are available in limited supply, the challenge lies in effectively allocating jobs to machines and distributing resources (denoted as R1) to minimize both the makespan and the cost associated with resources (denoted as R2).

In this study, we address an UPM scheduling problem incorporating two types of resource consumption and deterioration effects. Initially, we formulate a mathematical programming model, followed by the implementation of a multi-objective simulated annealing algorithm. Computational experiments are conducted across small, medium, and large instances. Ultimately, the results demonstrate that the MOSA algorithm consistently produces optimal solutions, particularly evident in the case of 15N3M instances.

The subsequent sections of the paper are organized as follows: the next section offers a comprehensive review of the literature on unrelated parallel machine problems, scheduling issues considering deterioration, resource constraints, and problems combining flexible resources and deterioration. In Section 3, we define the problem, outline its parameters, and explain the proposed mathematical programming model. Section 4 introduces the MOSA algorithm, detailing its adaptation to address this specific problem. Lastly, Section 5 offers an overview of experimental runs conducted with the MOSA algorithm.

II. LITERATURE REVIEW

The challenge of scheduling parallel machines continues to be a subject of extensive research, attracting numerous scholars due to its significant industrial relevance. As the findings from scientific studies find practical applications in industrial enhancements, the exploration of scenarios that closely mirror real-life

situations becomes increasingly compelling. In actual implementations, several resources are often required for job processing. For example, in [4], the authors investigated a scheduling problem involving unrelated parallel machines with additional resources. They proposed a mixed-integer programming model and developed a heuristic to address the problem. Similarly, [5] studied a comparable problem involving a single scarce additional resource.

Prior to that, [3] delved into a scheduling problem for parallel cells in printed circuit board manufacturing, where the processing time is influenced by the quantity of additional resources allocated to each job. The study proposed heuristics for both static and dynamic aspects of the problem. In [6], researchers explored the static identical parallel machine flexible resource scheduling problem with unspecified job allocation, employing ILP programs and suggesting heuristics. Subsequently, [7] investigated the dynamic variant of the problem.

As noted by [8], practically all scheduling problems involving parallel machines with non-renewable resource constraints are NP-hard, with only a few exceptions in specific cases.

Deterioration and resource-dependent processing times extend beyond job-specific instances, as evidenced by [9], which incorporated deterioration and resource dependency in maintenance activity durations. Furthermore, [10] and [11] introduced a combination of the deterioration effect and resource-dependent processing times in the context of minimizing a cost function comprising makespan, total completion time, total absolute differences in completion times, and total resource cost.

Scheduling problems, commonly classified as NP-hard, often limit the practical application of mathematical programming models to small instances. For instance, in [12], the MILP model efficiently addresses only very small instances, prompting the proposal of a decomposition algorithm to tackle the problem more effectively.

Given that most Unrelated Parallel Machine (UPM) scheduling problems fall into the category of NP-hard, lacking optimal algorithms, heuristics and metaheuristics emerge as highly efficient approaches, making them widely adopted in the literature.

For instance, [13] formulated a MILP model and devised an efficient two-step algorithm based on the multi-objective simulated annealing metaheuristic. In [14], both simulated annealing (SA) and a genetic algorithm (GA) are introduced to solve the static problem involving identical parallel machines with a joint server and sequence-dependent setup times. Similarly, [15] proposed a simulated annealing algorithm to minimize tardiness in a scenario of Unrelated Parallel Machines (UPM). [16] delved into an energy efficiency scheduling problem in the context of unrelated parallel machines subject to the deterioration effect. Following this, [17] addressed an unrelated parallel machines scheduling problem incorporating maintenance activities, employing an artificial bee colony algorithm to minimize either makespan or total tardiness. Additionally, [18] formulated a MILP model for an energy efficiency unrelated parallel machine scheduling problem.

All the studies mentioned above addressed a Unrelated Parallel Machine (UPM) scheduling problem, with some incorporating deterioration, others combining deterioration with one type of flexible resource consumption, yet none ventured into considering more than one type of resource.

In contrast to prior research, this paper contributes by introducing the consideration of multiple types of resources and the deterioration effect in a scheduling problem involving unrelated parallel machines. Regarding the resolution approach, to our knowledge, and despite its simplicity, only a handful of papers have put forth a

Multi-Objective Simulated Annealing (MOSA) algorithm and examined its performance in tackling such scheduling problems.

III.PROBLEM STATEMENT

The problem is defined as follows: there are n independent jobs to be processed across m unrelated parallel machines. Each job necessitates a minimum of one R1 resource for processing. Each machine can handle only one job at a time. The processing time of a job is characterized as an increasing function of its position and a decreasing function of the additional resources allocated to it. Specifically, the processing time for job j is expressed as follows:

$$Pr_j = a_{jr} + p_j . \alpha \qquad (1)$$

Where p_j is the position of job j, a_{jr} is the processing time of the job j processed with r additional resources. The objective is to minimize the makespan and the resources R2 cost.

Since the allocation of resources is static, there is no interruption during the schedule, and so the start time of a job processed in position p is the completion time of position (p-1), and the completion time of the final job in machine k is:

$$C_k = \sum_{p=1}^{P} Pr_{pk} \qquad (2)$$

We suppose that machine k consumes $\delta_k$energy per unit of time. The energy consumed by a machine k is given by the following equation:

$$E_k = \delta_k . \sum_{p=1}^{P} Pr_{pk} = \delta_k . C_k \qquad (3)$$

Parameters:

N number of jobs
M number of machines
Rmax maximum available resources
a_{jk} : Normal processing time of job j in machine k.
α: The deterioration rate.
β: Resources compression rate.
δ : The consumed energy per unit of time.
Pr_{pk} : Processing time of a job in position p machine k.
Rr_{pk} : Allocated resources to job in position p machine k.
R_k : Allocated resources to machine k.
R_{max} : Maximum resources available.
d_{pk} : Start time of job processed in position p machine k.
C_{pk} : Completion time of job processed in position p machine k.
C_k: Completion time of machine k.
C_{max}: Maximum completion time.

E_k: Cost of resources consumed by machine k.

TC: Total consumed resources' cost.

w_1, w_2: The weights of makespan and TC, respectively.

Decision variables:

$$X_{jpk} = \begin{cases} 1 \ if\ j\ is\ processed\ in\ position\ p\ machine\ k \\ 0\ else \end{cases}$$

$$x_{jk} = \begin{cases} 1 \ if\ machine\ k\ is\ selected\ to\ process\ job\ j \\ 0\ else \end{cases}$$

Mathematical programming model:

$$F = \min(w_1 . C_{max} + w_2 . TC) \quad (4)$$

$$\sum_{j=1}^{N} X_{jpk} \leq 1 \qquad \forall p, k \quad (5)$$

$$\sum_{k=1}^{M} \sum_{p=1}^{P} X_{jpk} = 1 \qquad \forall j \quad (6)$$

$$Pr_{pk} = \sum_{j=1}^{N} X_{jpk} . a_{jk} + \alpha . (p-1) - \beta . (r_{pk} - r_j) \qquad \forall p, k \quad (7)$$

$$r_{pk} = \sum_{j=1}^{N} X_{jpk} . r_j \qquad \forall p, k \quad (8)$$

$$r_{pk} \leq R_k \qquad \forall p, k \quad (9)$$

$$\sum_{k=1}^{m} R_k \leq R_{max} \qquad \forall j \quad (10)$$

$$d_{0k} = 0 \qquad \forall k \quad (11)$$

$$C_{pk} = d_{pk} + Pr_{pk} \qquad \forall p, k \quad (12)$$

$$d_{pk} = C_{(p-1)k} \qquad \forall k, p > 0 \quad (13)$$

$$C_{max} \geq C_{pk} \qquad \forall p, k \quad (14)$$

$$TC = \sum_{k=1}^{m} \delta_k \sum_{p=1}^{P} C_{pk} \quad (15)$$

The objective function is defined by equation (4). Equations (5) and (6) ensure that each machine processes at most one job per position and that each job is processed by a single machine, respectively. Equation (7) determines the processing time, which depends on its actual duration, the machine to which it is assigned, its position, and the amount of resources allocated to it. Equation (8) represents the resources allocated to the job being processed in position p on machine k. Equations (9) and (10) guarantee that the resources allocated to a processed job on machine k in position p do not exceed the available resources for machine k and that the total

resources allocated to the machines do not surpass the maximum available resources. Equations (11), (12), and (13) define the start time and completion time of the job processed in position p on machine k.

Since the allocation of resources is fixed throughout the entire time horizon, preventing idle times on a machine, equation (13) ensures that the completion time of a job in position p on machine k equals the start time of the job in the next position on the same machine. The makespan and the total cost of the consumed resources are calculated by equations (14) and (15).

Incorporating both objectives in the context of the UPM environment significantly amplifies the complexity and difficulty of the problem. Due to this heightened complexity, the mathematical programming model is limited to offering solutions for small instances. Consequently, a metaheuristic becomes essential to effectively tackle medium and large instances of the problem within a reasonable computation time.

IV. RESOLUTION APPROACH

This section introduces the application of a Multi-Objective Simulated Annealing (MOSA) algorithm tailored to address the complexities of this problem. Renowned for its user-friendly nature and claimed high efficiency, the MOSA algorithm is chosen for its adaptability to multi-objective scenarios.

Simulated Annealing (SA) stands out among metaheuristics for its reliance on solution modification. The SA algorithm employs one solution per iteration, streamlining the parameter-setting process and facilitating its application to this problem. In a study by [15], the performance of the SA metaheuristic is thoroughly analyzed, showcasing its effectiveness in solving unrelated parallel machine scheduling problems. Additionally, [19] introduced a MOSA algorithm to address the permutation flow shop scheduling problem, aiming to minimize both the makespan and total flow time of jobs. The algorithm's behavior is meticulously studied under various settings.

Before employing a metaheuristic, it is imperative to define the initial solution and integrate a perturbation scheme to generate a solution, S0, within the neighborhood of the initial solution (neighborhood generation method). Adapting the simulated annealing technique requires specifying key parameters, including the acceptance probability, initial temperature, epoch duration (number of iterations at a given temperature), cooling rate, final temperature, and stopping criterion.

Solution encoding: In the developed algorithm, solutions (chromosomes) are represented by two vectors table1 and 2:

i. A binary (n ×m) vector to define the assignment of jobs, where case equal to 1 if job j is processed in machine i, and equal to 0 otherwise. Table 1 illustrates an example of a coded assignment (n = 8, m = 3). According to this scheduling, jobs 6 and 7 are assigned to machine 1, jobs 2 3 4 and 8 are assigned to machine 2 and jobs 1 and 5 are assigned to machine 3.

ii. An integer (m) vector to define the amount of resources specified to each machine. Table 2 illustrates an example of a coded allocation. According to this example 2 resources are available for machines 1, 2 for machines 2 and only one resource is available to machine 3.

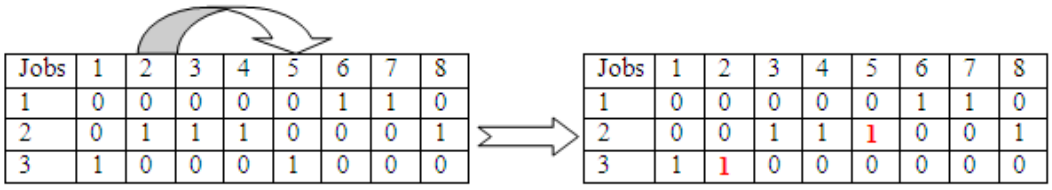

Fig. 2. The first movement to obtain a neighborhood solution

TABLE I. THE FIRST PART OF A CODED SOLUTION

Jobs	1	2	3	4	5	6	7	8
1	0	0	0	0	0	1	1	0
2	0	1	1	1	0	0	0	1
3	1	0	0	0	1	0	0	0

TABLE II. THE SECOND PART OF A CODED SOLUTION

Machine	Rk
1	2
2	2
3	1

A. Initial solution

In the simplest case, the initial solution may be randomly selected. However, to enhance algorithm performance, a heuristic is often applied (such as SPT, LPT, SRC, etc.). In our scenario, aiming to minimize makespan and resource costs in an Unrelated Parallel Machine (UPM) environment, we adopt a specific approach for the initial solution. Each job is initially assigned to the fastest machine, and additional resources are allocated to the machine with the largest completion time.

B. Neighborhood generation

Each new solution is derived from two random movements. The first movement or mutation involves changing the assignment of two randomly chosen jobs. The second movement consists of permuting between two machines, as illustrated in Figures 1 and 2, respectively.

Simulated Annealing involves a finite number of iterations repeated under decreasing temperatures. It is noted that:

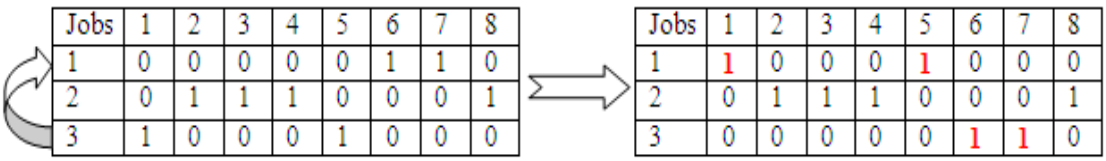

Fig. 1. The second movement to obtain a neighborhood solution

- Initial solution is disrupted to obtain new solution
- If the new solution is better than the initial one, or if it has a probability superior than acceptance probability, it will be the initial solution for the following iteration, else the initial solution for this iteration is kept for the following one.
- For each iteration, temperature decreases using the following relation: $T_n = \alpha . T_{n-1}$
- Iterations stop when stopping criterion is achieved.

C. Fixing the SA parameters

Inspired from [15] we fixe SA parameters as follows: Ti=8000, α=0.99, Pa=60%. Stopping criterion is theoretically achieved when T=0, but in practice that may not be achieved. So, after L=50 iterations without improvement, algorithm stops

The multi objective version of simulated annealing algorithm changes only when calculating the probability. Here we calculate probability of the two functions, and then we need a weight of function to aggregate probabilities to only one probability to be able to compare it with acceptance probability.

V. COMPUTATIONAL EXPERIMENT

In this section, the designed SA algorithm is tested on small instances (8N2M, 10N2M, 8N3M, and 10N3M), medium instances (40N4M, 50N4M and 60N5M) and larges instances (100N10M, 200N10M, 200N15M). Parameters of the system are generated randomly, according to the following distributions: normal processing time $a_{jk} = U(5,20)$, $\delta = U(1,3)$, $\delta_k = U(1,3)$. $a_{jkr}$is calculated by extracting 15% from a_j for each one additional resource added. Rmax is randomly generated according to U((M-1),(2M)). W1, w2 and β are fixed to 0.5, 0.5, and 0.2 respectively.

To judge the algorithm performances, we compare (as long as possible) its results with the optimal solution given by the mathematical programming model, using Lingo as solver.

It is clearly remarkable, by comparing Lingo and MOSA results, that MOSA gives optimal solution, at least for instances solvable by the mathematical programming model. And from there we can say that even for medium and large instances MOSA algorithm converges towards the optimum.

VI. CONCLUSION

In this study, we delved into a scheduling problem involving unrelated parallel machines, assuming the presence of two distinct resources, namely R1 and R2. R1, categorized as renewable resources, governs the processing time, while R2, classified as non-renewable resources, is contingent upon the processing times of all jobs. For the static version of the problem, we formulated an Integer Linear Programming (ILP) model. Despite the inherent complexity of the problem, the ILP model demonstrated efficiency by providing solutions for instances comprising up to 15 jobs and three machines in under 10 minutes.

As an alternative solution approach, we applied the Multi-Objective Simulated Annealing algorithm (MOSA) to address the problem. Computational experiments were conducted to validate the ILP model and assess the performance of the MOSA algorithm. The results indicated that the MOSA algorithm's performance approached optimal solutions for instances already solved by the ILP model.

Looking ahead, our future research endeavors in this area will focus on:

i. Exploring the dynamic version of the problem.

ii. Incorporating maintenance activities to restore machines and minimize the deterioration effect.

iii. Improving the algorithm by enhancing the initial solution or the neighborhood generation method.

iv. Developing alternative approaches to validate the efficiency of the algorithm, such as exploring lower bounds or examining all possible solutions for specific instances.

TABLE III. LINGO AND MOSA RESULTS FOR SMALL MEDIUM AND LARGE INSTANCES

Instances		Lingo	MOSA	Instances		MOSA
8N2M	I1	66.48	66.48	40N4M	I9	517.2
	I2	75.5	75.5		I10	434.37
8N3M	I3	86.94	87.78	50N4M	I11	719.4
	I4	87.05	87.05		I12	726.6
10N3M	I5	76.48	76.76	60N5M	I13	645.11
	I6	110.78	110.78		I14	640.26
15N3M	I7	139.55	139.55	100N10N	I15	911.2
	I8	154.44	154.84		I16	987.8

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Harmonious Discord: A Study of Ecological Consciousness in Kiran Desai's Hullabaloo in the Guava Orchard

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ABSTRACT

This paper explores the intricate narrative of Kiran Desai's Hullabaloo in the Guava Orchard through the lens of ecocriticism, unraveling the ecological consciousness embedded within the text. By juxtaposing the protagonist Sampath Chawla's yearning for a harmonious existence with nature against the backdrop of a society entrenched in anthropocentrism, Desai crafts a compelling critique of modernity's materialistic pursuits. This analysis delves into the dichotomy between the tranquil refuge offered by the natural world and the chaotic dissatisfaction spawned by human-centered ideologies. The novel emerges as a poignant reflection on the necessity for a symbiotic relationship between humans and the environment, challenging the prevailing anthropocentric worldview that prioritizes human needs at the expense of nature's integrity. Through Sampath's journey and the vivid portrayal of the guava orchard as a space of ecological resistance, Desai articulates a critical discourse on environmental degradation and the potential for ecological redemption. This study underscores the importance of fostering ecological awareness and sustainability, advocating for a shift towards more inclusive and respectful interactions with our planet. Hullabaloo in the Guava Orchard serves as a narrative catalyst for ecological awakening, emphasizing that genuine contentment and peace are attainable only through a life aligned with the rhythms of the natural world.

Keywords : Ecocriticism, Kiran Desai, Anthropocentrism, Environmental consciousness, Nature vs. modernity, Ecological sustainability, Harmonious coexistence, Materialism critique, Ecological redemption

I. INTRODUCTION

Ecological crises are becoming more common as a result of people losing faith in conventional wisdom and acting unethically, which undermines the need of protecting the natural world and its non-human inhabitants. Deep ecology is a way of thinking that guides human actions towards non-destructive coexistence with the natural world. Critical scholars in the field of Deep Ecology examine "literary texts with reference to the interaction between human activity and the vast range of 'natural' or non-human...," a method developed in response to the contemporary ecological and environmental crises. (Childs and Fowler 65).

According to Glotfelty (XVIII), "the study of the relationship between literature and physical environment" is known as Ecocriticism in the field of critical theory. *The God of Small Things* (1997) by Arundhati Roy, *The*

Hungry Tide (2004) by Amitav Ghosh, *The Lowland* (2013) by Jhumpa Lahiri, etc. are only a few examples of modern Indian English novels that touch on the exploitation of non-human worlds. All of these works, according to ecocritical interpretations, take on an ecological concern. Among the modern Indian English books written by Kiran Desai that sound environmentally concerned is *Hullabaloo in the Guava Orchard*.

An explanation of ecocriticism is provided by the Routledge Dictionary of Literary Terms:

"The study of literary texts with reference to the interaction between human activity and the vast range of 'natural' or non-human phenomena which bears upon human experience – encompassing (amongst many things) issues concerning fauna, flora, landscape, environment and weather" (Childs and Fowler 65).

Actually, ecocriticism is analysing a piece of literature in relation to the problems of the current ecological and environmental catastrophe. 'Ecocriticism truly launches a call to literature to link to the challenges of today's environmental crisis,' (Oppermann) writes in one of his articles. "The critical and pedagogical broadening of literary studies to include texts that deal with the non-human world and our relationship to it" (Cokinos 3), according to Kansas State University's Christopher Cokinos in his position paper 'What Is Ecocriticism). Ecocriticism is on analysing literary works via an Earth-centered lens. Studying the relationship between a literary work and its surroundings is central to this field, which aims to foster an ecological awareness in humans.

Ecocriticism is now being promoted by the American Association for the Study of Literature and the Environment (ASLE), which was founded in 1992. The ASLE official website displays

"ASLE seeks to inspire and promote intellectual work in the environmental humanities and arts. Our vision is an inclusive community whose members are committed to environmental research, education, literature, art and service, environmental justice, and ecological sustainability" (ASLE).

In a similar vein, OSLE-India is a platform that promotes ecocriticism, particularly in India and other Asian nations.

'Ecological Consciousness' is a combination of the two distinct nouns' meanings. "Ecological" is an adjective form of the noun "ecology." Since "ecology" is defined as "a science that deals with the relationship between groups of living things and their environment" (Merriam), it can be extended to mean "the relation between a group of living things and their environment" (Merriam). "Consciousness" is being aware of, or cognizant of, anything that is going on in one's immediate environment. To be ecologically conscious is to be aware of one's place in the natural world in this context. That is, what is happening in our ecosystem, the benefits it offers, and any threats it faces.

Even though the Renaissance came to a close in England in 1660, the core principle of "humanism" from the period has remained with humanity ever since; however, in the modern world, we are confronted with a warped version of this "humanism," namely, anthropocentrism. Anthropocentrism holds that all non-human entities should be sacrificed in order to advance humanity's economic and technological capabilities. With that in mind, we may say that Anthropocentrism is the belief that humans are the centre of the universe. In reality, the Greeks were the ones who popularised this human-centered view of existence. The Greeks were

the first to see humanity as an integral component of a complex ecosystem, rather than an independent species, according to the Routledge Dictionary of Literary Terms. The source is Children and Fowler, page 65. Anthropocentrism is the dominant worldview in environmental studies, which holds that human activities are the primary cause of environmental degradation.

Many things come together to produce *Hullabaloo in the Guava Orchard* a book that cares about the environment. While the rest of the novel's characters have long since lost touch with the non-human world, protagonist Sampath Chawla demonstrates his ties to it. When it comes to the ecological disaster, Sampath feels it all too well. It is clear that he feels sorry for the Shahkot monkeys. However, the work also highlights the other characters' anthropocentricism, which readers can see throughout. From two different perspectives, the novel's ecological core shines through. First, the novel's verdant language and Sampath's perspective on non-humans bring to mind a Wordsworthian understanding of nature—namely, nature as a place of solace and calm. Second, the novel's other characters' anthropocentric viewpoints demonstrate how indifferent man has become towards the non-human realm. From an ecocritical perspective, the book makes a strong case for the idea that genuine peace still comes from Nature; but, man seeks peace away from Nature, which can never provide him satisfaction.

Kiran Desai's use of words is replete with vivid imagery that portrays the beauty of nature. Along these lines, you may feel the dominant petrichor when the first rains arrive in Shahkot. There was a monsoon in town. The scent of rain tinged the air like a flower as Kulfi eagerly watched the clouds roll in from the east, pass the trees on the outskirts of town, and then continue on (Desai 9). You can feel the soothing spirit of nature permeating the text the whole way through. The story also stresses that Nature has the ability to repair itself. In order to keep the ecosystem in equilibrium, nature fixes everything on its own. Earth isn't only for humans, and humans can't exist forever without other species. The interaction between man and nature ought to be mutually beneficial. Nature, via climatic shifts, affords all living things an opportunity to flourish. 'Soon the winged ants would be flying and lizards would get fat on hundreds of reproducing insects..' The book recounts the transformations and vitality of Nature following the rain in Shahkot. Green, voluptuous fungus and mould would spring up, and legions of mushrooms would congregate in the cabinet beneath the sink. As stated by Desai, in point 12. Sampath Chawla's (the novel's protagonist) sentiments for Nature are as enthralling as those of any Lake romantic poet. "Oh, if he could exchange his life for this luxury of stillness, to be able to stay with his face held towards the afternoon like a sunflower and to learn all there was to know in this orchard," the author writes of his ambition to live in harmony with Nature, his use of Nature as a teacher, and the tranquilly he experiences while lying in Nature's lap (Desai 51).

Sampath was tasked with filling glasses with sherbet during the wedding of Mr. D.P.S.'s daughter. Not only that, but he also needed to replace the empty glasses after washing them. But as he stepped into a room adorned with bridal attire, his need for the untamed, the mysterious, the organic, and the tranquil took over.

'He uncorked a bottle of rose-water... Sampath...could also discern the scent of musk, mothballs, marigolds and baby powder. Of sandalwood oil. Oh, scented world! He felthis heart grow light' (Desai 37).

'... he felt a sudden sharp longing, a craving for an imagined world, for something he'd never known but felt deep within himself' (Desai 38).

Every time Sampath wants to break free of the daily life's restrictions and experience nature more fully, he does something that the inhabitants of Shahkot find strange and unrealistic. At the conclusion of chapter five of the book, Sampath finally understood what he desired—"his freedom"—after being frustrated by the way others treated him following his strange conduct at the wedding (Desai 47).

Sampath eventually made his home in the guava orchard, and it was quite similar to his childhood fantasies: a "myriad green-skinned globe growing sweet-sour and marvellous upon a hillside with enough trees to fill the eye and enough fruit to scent the air" (Desai 50). Sampath's defence of intoxicated monkeys is another example of his compassion for animals. With the phrase "What can they possibly know?" he humorously defended the monkeys. The little one lights up his dad's hookah when everyone else is fast asleep (Desai 123).

Similar to Wordsworth's writings, the protagonist in the book finds solace in Nature. "Yes, he was in the right place at last"—the novel's protagonist Sampath—achieves true serenity via mending his relationship with nature, dispelling the contemporary man's false belief that human advancement away from the natural world will bring about harmony. He closed his eyes and slept off when wedged in a guava tree's fork, overcome by exhaustion (Desai 51).

While reading *Hullabaloo in the Guava Orchard*, one may also feel the anthropocentrism. The family's wealth motivated Mr. Chawla, Sampath's father, to sell his son as a religious commodity. Despite Sampath's growing fame as Monkey Baba, his father considered turning the orchard into a tourist attraction, even though it would mean sacrificing his son's happiness. Although Sampath had sought solace in a life of seclusion away from his town and its artificial civilization, his father had built the very same world in the orchard, causing Sampath much pain and suffering.

The following words from chapter eleven of the book demonstrate Man's callousness towards animals: "I have fed the food to a chicken beforehand to make sure it is not poisonous" (Desai 103). Kulfi cooked something for Sampath that she hadn't tried on chicken before since she was worried it may contain toxic substances. The life of a chicken meant nothing to Kulfi. As time went on, Sampath appointed a new chicken as his official tester. New ones were held in place by tethering them whenever one of them keeled over and died, whether from natural causes or contaminated food (Desai 103). Kulfi stands in for all the people who subject animals to cruel and deadly experiments. People are the most important thing in the world to them.

Their treatment of the monkeys that lived in Shahkot was only another indication of the pervasive anthropocentrism in the narrative. Who was really at fault, the man or the monkeys? Surely there were plenty of times when the monkeys were the bad guys. The habit of alcohol use by monkeys could not have arisen without the carelessness of the man who abandoned bottles of alcohol in the orchard, from whence the monkeys obtained them. "It is not the monkeys' fault," one Sampath follower told Desai, allowing him to act as a spokesperson for monkeys. The depraved one is always a man (Desai 123).

Several characters propose human-centered strategies to exterminate the monkeys, revealing that humanity views Earth as exclusively belonging to itself and that it is its owner to determine what should and should not be there. Verma of the university developed a plan that included a peculiar way of murdering the Cinema

Monkey and exhibiting its corpse in order to dissolve the company. 'They would split apart and blend in with the jungle,' (Desai 161). This was in line with what the Brigadier had previously said,

'...organise a firing squad whereby fifty or a hundred men would be dispersed throughout the brush, discharging their rifles every twenty to forty minutes to scare the monkeys. the monkeys would surely get the jitters and would disappear from there, never to return' (Desai 162).

The novel's proposed anthropocentric remedies to the monkey problem illustrate how callous humans have become towards the natural world. In chapter 23 of the book, Sampath says, "Leave me alone, I am going to be sick," revealing his powerlessness. "Just give me some space," she pleaded. The source cited is Desai (1990). These lines encapsulate the sentiments of everyone whose autonomy has been eroded by the artificial society. A new low point in the ever-deepening anthropocentrism is the idea that man governs other humans so that they can fit into his universe and that he also chooses what kinds of non-humans should exist.

Ecocritical reading of literary texts has arisen as a means for literary academics to engage in environmental activism and raise ecological consciousness among readers in this period of environmental crises. For the same reason, this article also offers an ecocritical interpretation of *Hullabaloo in the Guava Orchard* by Kiran Desai. While the book does a good job of reminding readers of the calming effects of nature, it also shows how human-centered our society is. In *Hullabaloo in the Guava Orchard*, we see modern India, where a person going through adolescence may feel out of place in an anthropocentric culture that has long forgotten the importance of the natural world. When the story came to a close, Sampath had sought solace in the orchard and the monkeys had followed suit. However, the villagers had mistakenly believed that Sampath had become a guava. Man with an anthropocentric mindset is oblivious to what he has been losing since he lives in his own fictional world, which is symbolised by this conclusion. Tragically, Sampath's father's insatiable greed caused him to lose his son.

While the novel's characters offered various remedies to the monkey problem, they all concluded by predicting that the monkeys would flee into the forest. It reveals how people think ironically. The first step is for humans to chop down trees for fuel and timber. This pushes animals to from their natural habitats, and when those animals eventually make it to the man-made towns and cities that have sprung up in the forest's vacated spaces, humans employ a variety of tactics to drive them back into the woods. I can't find those woods. Such beings, where would they go? Do you think man can provide satisfactory answers to these questions?

Without a doubt, *Hullabaloo in the Guava Orchard* draws readers' attention to the growing ecological issue while simultaneously presenting Nature as the ultimate refuge from chaos.

Conclusion

The novel *Hullabaloo in the Guava Orchard* by Kiran Desai serves as a profound narrative that not only entertains but also educates and invokes deep reflection on the interconnections between humans and nature, alongside the stark realities of a society deeply entrenched in materialism. Through the journey of Sampath Chawla, who seeks refuge and solace in the embrace of nature away from the cacophony of city life, Desai masterfully unveils the essence of ecological consciousness and the inherent value of the natural world in

providing mental and physical respite. This work, as analyzed through the lens of eco-criticism, highlights the stark contrast between the serene, sustaining forces of nature and the tumultuous, often unsatisfying pursuit of material wealth, thereby echoing the deep ecological principle of harmonious coexistence with the environment. The novel emerges as a poignant critique of anthropocentrism, revealing the detrimental effects of placing humans at the center of existence to the detriment of the natural world and its myriad non-human inhabitants. By illustrating the various anthropocentric attitudes and actions of its characters towards environmental elements, particularly the guava orchard and its monkey inhabitants, Desai not only critiques the prevailing disregard for nature but also underscores the potential for redemption through a rekindled connection with the natural world. *Hullabaloo in the Guava Orchard* thus becomes a clarion call for ecological awareness and sustainability, urging readers to reconsider their relationship with nature and advocate for a more inclusive, respectful, and sustainable interaction with our planet. It reaffirms the notion that true peace and fulfillment lie not in the relentless accumulation of material possessions but in a life lived in harmony with the natural world. In essence, Desai's novel is a compelling narrative that weaves together themes of escape, environmental consciousness, and the quest for authenticity in a world overshadowed by materialism, offering insightful perspectives on the urgent need for an ecological reawakening in contemporary society.

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A Vehicle Routing Problem with Particular Constraints Application to Hemodialysis Home Hospitalization

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ABSTRACT

In this article, the focus is on addressing the vehicle routing problem (VRP) in the context of the home care sector. Specifically, the VRPTW-SP variant of the VRP is examined, which takes into account time constraints, time windows, synchronization, and precedence. The aim is to establish an effective strategy for daily caregiver visits to patients' homes, ensuring that all necessary services are provided in a timely and efficient manner. By solving this problem, the home care sector can optimize its resources, reduce costs, and improve the quality of care provided to patients.

We used a mono-objective approach to address the VRPTW-SP problem in the home care sector, and we developed a mathematical model based on a detailed description of the formal data. The effectiveness of this model was then evaluated using the Cplex solver, which is a Linear Program with Integer Mixed Variables (PLME). In addition to this, we developed two constructive heuristics and two local search procedures that were tailored specifically to this problem. Finally, we present the outcomes produced by these different resolution techniques.

Keywords : Combinatorial Optimization; Transportation; Planning; Synchronization; Home Care; Heuristics; Multi-criteria Decision; Mathematical Models.

I. INTRODUCTION

Hemodialisis home hospitalization refers to alternative healthcare structures that provide medical and paramedical care in the patient's home. HADs offer a solution for patients who require medical attention but wish to avoid hospitalization. With HAD, patients can receive quality medical care in the comfort of their homes.

The purpose of establishing these structures was to initiate reductions in real estate and mobility costs (fixed costs) while maintaining a satisfactory level of service quality. However, the development of these structures is accelerating, and specific studies are necessary to optimize the expenses related to their functioning.

The obligation to control healthcare expenses appears to be a necessary and sufficient reason to initiate logistics restructuring efforts. These issues highlight the need to make a significant contribution to the performance of the healthcare system by providing the right care or products at the right time and at a lower cost while preserving service quality.

This study focuses on the organization of hospital and home care structures. Research in this sector aims to establish a fine coordination and optimized planning of human and material resources to ensure quality care and follow-up while controlling costs. Care is usually provided at specific times and may sometimes require the simultaneous intervention of multiple qualified caregivers. The main objective in this case is to plan, synchronize, and coordinate activities to provide an optimized organization that enables access to care without resorting to traditional hospitalization.

By associating patients with customers and caregivers with vehicles, the problem introduced in this article can be defined as a variant of the vehicle routing problem where the requested care must be provided at specific times by qualified caregivers. This variant will be referred to as the VRPTW-SP (Vehicle Routing Problem with Time Window, Synchronization, and Precedence constraints), where certain customers require multiple services simultaneously or in a predefined order. The optimization criteria involve minimizing the travel costs of caregivers while maximizing patient satisfaction.

Before presenting the resolution techniques we have proposed for the Vehicle Routing Problem with Time Windows, Synchronization, and Precedence constraints (VRPTW-SP), it is important to clearly state the problem and the assumptions we have made. In Section 2, we explain the interest and reasons that motivated our study and led us to investigate this problem. Then, a formal description is given in Section 3, allowing us to write the mathematical model. Sections 4 and 5 are devoted to the tools dedicated to solving the routing problem with synchronization and time windows, namely the construction heuristics and local search procedures. The results obtained by these different resolution techniques are presented in Section 6. Finally, the manuscript concludes with Section 7.

II. Previous work and Motivation

Logistics research in healthcare was first proposed by Bodin and Sexton (1986) and Desrosiers et al. (1986-1995). Later, Rousseau et al. (2003, 2013) proposed a specific variant of the problem. These authors discussed the importance of introducing synchronization constraints to manage priorities between visits. More recently, Coppi et al. (2013) introduced a new variant with time windows, in which the objective is to plan hospital care. However, patients are transported from their homes to the hospital under urgent conditions, and the optimization criterion concerns the minimization of costs associated with transportation.

The home care problem phenomenon was extended by Cheng and Rich (1998), where medical staff are assigned to patients' homes. They proposed a mixed-integer linear programming (MILP) model and developed a heuristic to solve this type of problem. Eveborn et al. (2006) formulated this problem as a partitioning problem with a periodicity constraint. Akjiratikarl et al. (2007) proposed an approximate population-based method called particle swarm optimization to minimize the distance traveled by each caregiver while respecting vehicle capacities and visit time windows. Trautsamwieser and Hirsch (2011) proposed a metaheuristic mathematical formulation based on variable neighborhood search to optimize home care planning. Dorner et al. (2007) focused on the location-routing problem with a multi-objective formulation.

However, due to its complexity, the healthcare system hides a large number and a great diversity of decision-making processes that challenge researchers in the field of Operations Research and Decision Support. Many improvements are possible, whether in terms of the objective of effectiveness (improvement of the quality of care) or efficiency (ensuring the mission at the lowest cost).

In particular, the costs associated with HAD are largely due to transportation. The main goal of this research work is to establish the planning of

healthcare professionals' visits by optimizing the costs related to their travel while ensuring a quality of service and medical follow-up equivalent to that given in traditional healthcare settings (hospitals). However, several characteristics have been identified, including the presence of availability windows for patients/caregivers, the need to receive one or more specific treatments that may be subject to time constraints, and the qualification of the personnel (some providers may not be able to perform certain categories of care).

The number of existing works on the subject and incorporating these different aspects is low, particularly for cases combining both types of synchronization constraints (simultaneous and prioritized). However, some authors have addressed the resolution of a similar problem integrating these two categories of constraints, by proposing a mathematical modeling approach duplicating the nodes corresponding to patients who have requested services to be synchronized.

This modeling is interesting but remains impractical from a complexity standpoint, especially as the original graph size increases. Let's imagine that we have n patients to visit and each one requests m services. The number of nodes in the resulting graph would be $n \times m$. Labadie et al. (2014) proposed a modeling approach that keeps the size to n nodes. However, they only addressed simultaneous synchronization constraints. Thus, their main objective was to minimize caregiver travel costs. At this stage, numerical results were reported for relatively small instances.

To achieve this, we propose to first manage both types of synchronization constraints within a single model, without duplicating nodes, and to introduce an important optimization criterion in improving the quality of service of home care facilities, which is to maximize patient satisfaction. We will also propose new feasibility tests to integrate temporal constraints into local search movements. These techniques are a generalization of the feasibility tests proposed by Kindervater & Savelsbergh (1997), efficiently adapted to the problem studied in this article and which remain applicable in $O(1)$

III. List of data and constraints.

Formally, the VRPTW-SP is defined on a directed graph $G(V,E)$ where $V = N \cup D$ is the set of nodes, and $N = \{1,.....n\}$ is the set of customers, and $D = \{0, n+1\}$ represent respectively the initial depot (from where vehicles start their tours) and the final depot (that vehicles reach at the end of their tours).

$E = \{(i,j) : i,j \in V, i \neq j\}$ is the set of edges connecting the customers to each other, the initial depot, and the customers and final depot (customers and final depot are connected). Each edge $e = (i,j) \in E$ is weighted by a positive value T_e representing the relative duration of travel on that edge, as well as a travel cost C_e $C_{o,n+1} = +\infty$ and $T_{0,n+1} = 0)$ a service cost $S = \{1,.....s\}$ is the set of available services. A patient can request one or several different services. To do this, we define S_i as the set of services requested by customer i such that $S_i = \{s \in S : m_{is} = 1\}$,where m_{is} is a given parameter equal to 1 if the customer i requests service s , and 0 otherwise. Each customer $i \in N$ also has a time window $[a_i, b_i]$ representing their availability at home and visit duration D_{is} for each service s requested by $i(D_{0s} = D_{n+1,s} = 0)$

A limited fleet of vehicles is available at the initial depot (0) , each corresponding to a specific caregiver. Let K be the set of vehicles, each offering a specific service. Each vehicle $k \in K$ is associated with a time window $[\alpha_k, \beta_k]$, where α_k represents the time at which vehicle k can leave the initial depot (0) ,

and β_k corresponds to the time at which vehicle k must return to the final depot $(n+1)$.

A non-preference coefficient $pref_{ik}$ is assigned by each customer i to evaluate the caregiver k qualified to perform the requested service. In this study, we assume that each vehicle (caregiver) $k \in K$ is capable of performing only one type of service s , specified by the parameter o_{ks} which equals 1 when vehicle k offers service s . Thus, we define K_s as the set of vehicles offering service s as follows: $K_s = \{k \in K : o_{ks} = 1\}$. For simplicity, we write $k \in K_s$ if $o_{ks} = 1$ and $s \in S_i$ if $m_{is} = 1$.

The problem consists of determining the set of tours taken by the fleet of vehicles, starting from the initial depot and serving a subset of customers who demand the service corresponding to their caregiver's qualification, before returning to the final depot. The tour of each vehicle must not exceed the duration imposed by its time window, thus the time windows of the customers must be respected.

As we have already explained, the particularity of this problem lies in the fact that a customer may request multiple services simultaneously or in a given order. To address this, we define gap_{isr} as the duration between the start of services s and r at customer i. Indeed, this gap is strictly positive in the case of a priority synchronization such that $gap_{isr} = gap_{irs}$. On the other hand gap_{isr} is zero when services s and r must be performed at the same time, in the case of a simultaneous synchronization. Such a customer will be called a synchronized customer. The constraints of this problem are as follows:

Every vehicle k must start its tour from the initial depot (0) after α_k and must imperatively return to the final depot $(n+1)$ no later than at the moment β_k .

The requests of all customers must be fulfilled.

The start of service at any customer i must take place by the qualified vehicle and within $[a_i, b_i]$.

The desired gap between the services to be synchronized must be respected.

The goal is to answer the following question: When are the customers served ? And by which vehicles ? In a way that minimizes the travel costs and maximizes the customer satisfaction. The latter is translated by minimizing the non-preferences of the customers towards the vehicles.

IV. Notations:

$Ecart_{ij}$ is the minimum time separating the start of service at patients i and j .

y_i is a binary variable equal to 1 if patient $i \in N$ is not visited, 0 otherwise."

Bredström & Rönnqvist (2008) and Rasmussen et al. (2012) proposed a linear program based on an augmented graph in which a synchronized visit corresponds to a node per requested caregiver. That is, for each patient i requiring n_i visit, $(n_i - 1)$ nodes are added to the graph, inducing a total number of nodes equal to $(\sum_{i=1}^{n} n_i)$.

Indeed, Bredström & Rönnqvist (2008) designated the set of visit pairs to be synchronized by $P^{sync} \subset N \times N$, where a customer j is virtual in a pair $(i, j) \in P^{sync}$ when i and j correspond to the same patient. Thus, the constraints for simultaneous synchronization are defined as follows:

$$\forall (i, j) \in P^{sync} \sum_{k \in K} t_{ik} = \sum_{k \in K} t_{jk} \qquad (1)$$

Rasmussen et al. (2012) defined the set of synchronization pairs $P \subset N \times N$. Thus, the time constraints (both simultaneous and priority synchronization) are defined as follows:

$$\forall (i, j) \in P \qquad a_i y_i + \sum_{k \in K} t_{ik} + Ecart_{ij} \leq \sum_{k \in K} t_{jk} + b_i y_i$$

where $(Ecart_{ij} = Ecart_{ji})$ and $Ecart_{ij} = 0$. We are in a case of simultaneous synchronization. However, Labadie et al. (2014) provided a new formulation to avoid the duplication of synchronized nodes (related to patients), by considering a set of requested services for each patient. Thus, simultaneous synchronization was formulated as follows:

$$\forall_i \in N_1 \quad \forall_{p1\,p2} \quad = 1,\ldots|S|$$

$$v_{i,p1}.v_{i,p2} \sum_{k\in Kp1} t_{ik} = v_{ip1}.v_{i,p2} \sum_{k\in Kp2} t_{ik}$$

where $v_{i,p1}$ and $v_{i,p2}$ are data, which take the value 1 if patient i requests services p_1 (resp p_2) , 0 otherwise.

V. mathematical Model

The VRPTW-SP can be formulated as a mixed integer linear program (MILP), involving two types of variables: binary routing variables and scheduling variables denoted.

$x_{ijk} = 1$ if vehicle $k \in K$ crossing edge $(i, j) \in E$, 0 otherwise.

$t_{ik} \geq 0$ denotes the time at which vehicle k begins performing the service requested by customer i .

The problem can be written in its mathematical formulation as follows:

$$min \sum_{e\in E}\sum_{k\in K} C_e.x_{ek} + \sum_{i\in N}\sum_{j\in|\{0\}\rangle}\sum_{k\in K} Pref_{ik}.x_{ijk} \qquad (2)$$

Subject to the constraints:

$$\sum_{j\in N} x_{0jk} = 1 \qquad \forall k \in K \quad (3)$$

$$\sum_{i\in N} x_{in+1k} = 1 \qquad \forall k \in K \quad (4)$$

$$\sum_{i\in V} x_{ihk} = \sum_{j\in V} x_{hjk} \qquad \forall k \in K \quad (5)$$

$$\sum_{j\in V}\sum_{k\in K} x_{ijk} = m_{is} \qquad \forall i \in N, \forall s \in S \quad (6)$$

$$t_{ik} + (T_{ij} + D_{is}.x_{ijk} \leq t_{jk} + b_i(1 - x_{ijk})$$
$$\forall i, j \in V, \forall s \in S_i \cap S_j, \forall k \in K_s \qquad (7)$$

$$a_i \sum_{j\in N} x_{ijk} \leq t_{ik} \leq b_i \sum_{j\in N} x_{ijk} \quad \forall i \in N, \forall s \in S_i, \forall k \in K_s \quad (8)$$

$$\alpha_k \leq t_{0k} \leq \beta_k \qquad \forall k \in K \quad (9)$$

$$\alpha_k \leq t_{n+1k} \leq \beta_k \qquad \forall k \in K \quad (10)$$

$$\sum_{k\in K_s} t_{ik} - \sum_{k\in K_s} t_{ik} \leq gap_{isr}\,, \ \forall i \in N, \forall s, r \in S_i : r \neq s \quad (11)$$

$$\sum_{k\in K_s} t_{ik} - \sum_{k\in K_s} t_{ik} \geq -gap_{isr}\,, \ \forall i \in N, \forall s, r \in S_i : r \neq s \quad (12)$$

$$\sum_{k\in K_s} t_{ik} - \sum_{k\in K_s} t_{ik} \geq gap_{isr} - Mz_i\,, \forall i \in N, \forall s, r \in S_i, r \neq s \quad (13)$$

$$\sum_{k\in K_s} t_{ik} - \sum_{k\in K_s} t_{ik} \leq -gap_{isr} + M(1 - z_i)$$
$$\forall i \in N, \forall s, r \in S_i : r \neq s \qquad (14)$$

$$x_{ijk} \in \{0,1\}$$

$$t_{ik} \geq 0$$

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

Under this formulation, the objective function (2) incorporates the costs defined previously. Constraints (3-6) are routing constraints, where constraints (3) (resp. (4)) specify that each vehicle leaves (resp. returns to) the depot exactly once. Flow conservation constraints are given in (5). Constraints (6) ensure that the demands of all customers are met. Constraints (7) are scheduling constraints and ensure the consistency of visit times. Constraints (8-10) are punctuality constraints that ensure that the time windows of customers (resp. vehicles) are respected. Constraints (11-14) are synchronization constraints ensuring the coordination of visit times of different vehicles serving a customer requesting more than one service. The latter is the linearization of the following non-linear constraint:

$\forall i \in N, \forall s, r \in S_i : r \neq s \left| \sum_{k\in K_s} t_{ik} - \sum_{k\in K_r} t_{ik} \right| = gap_{isr}$ by introducing the binary variable z_i which equals 0 if $\sum_{k\in K_s} t_{ik} \geq \sum_{k\in K_r} t_{ik}$. and a large value M that we

initialize to $\max_{k\in K}\beta_k + \max_{i\in N,s,r\in S:s\neq r} gap_{isr} + 1$. Finally, constraints 15 and 17 fix the nature of the decision variables.

A. Resolution using a constructive heuristic

The first developed method for solving real-size problems is based on constructive heuristics in order to provide high-quality solutions within a reasonable computing time. The construction of such a solution generally results from a sequence of elementary decisions.

Two greedy heuristics are proposed, each following a particular insertion strategy. The first is a sequential approach consisting of constructing the tours one after the other. The second is a parallel approach consisting of constructing the tours simultaneously. In both versions that we present later, the tours are developed using the nearest neighbor algorithm, and a set of priority rules is applied to choose the best customer to insert into a tour. In both cases, the choice of the vehicle to use is deterministic, unlike the selection of the customer to insert, which adopts a randomized approach. The randomization is based on a list of "candidate" customers that can be inserted into the tour being constructed, and allows for the generation of multiple solutions in case of successive calls.

Before detailing the two strategies, we present the common parts, namely the construction of the list of candidate customers and the selection criteria used to choose the customer to insert.

B. Building the candidate list.

Let us first list the notations used in this section. Let D_{is} denote the service duration s requested by the customer i, T_{ij} the tour duration between customers i and j, a_i (resp. b_i) correspond to the start (resp. end) time of the time window of customer i, and β_k corresponds to the end time of the vehicle's availability k, $time_{is}$ corresponds to the start time of service at customer s. In what follows, let d denote the initial depot and f denote the final depot.

To construct the list of candidate customers L_i for insertion after customer i (at the first iteration i, is the initial depot 0, and we have $D_{is}=0$) in the vehicle's tour k, we first calculate for all customers j not yet assigned to a tour and requesting service s: an earliest possible date $Edat_{ij}$ which corresponds to the time at which customer j can be reached from i, a latest possible date $Ldat_{ij}$ which corresponds to the maximum time at which customer j can be inserted after i, as well as a lower bound BI_{js} and an upper bound BS_{js} calculated as follows:

$$Edat_{ij} = time_{is} + D_{is} + T_{ij}$$
$$Ldat_{ij} = \beta_k - T_{if} - D_{js}$$
$$BI_{js} = \max\{a_j, Edat_{ij}\}$$
$$BS_{js} = \min\{b_j, Ldat_{ij}\}$$

A customer j is considered reachable from i and included in the list L_i if the latter satisfies the following three conditions:

$$Edat_{ij} \le b_j$$
$$Ldat_{ij} \ge Edat_{ij}$$
$$BI_{js} \le time_{js} \le BS_{js}$$

C. Sorting criteria for the selection list: Three strategies are considered for sorting the list L_i.

C_1 : Increase order of BI_{js}

C_2 : Increase order of BS_{js}

C_3 : Increase order of $BS_{js}(BS_{js} - BI_{js})$

Only one sorting criterion is considered at a time, resulting in three different versions associated with each strategy. The results obtained will be presented in section 5. The names of these versions will have the following format: $A-B$ where $A\in P$ for a parallel

strategy and $A \in S$ for a sequential strategy, and $B \in \{C_1, C_2, C_3\}$ corresponding to the selected sorting criterion. Algorithm (1) describes the construction of the list L_i :

Algorithm 1. ConstructionCandidates $i, k, s : CL$

1 : *CltRest* : *All Customers not yet inserted*
2: $L_i = \phi$
3: *for* $j \in$ *CltRest Do*
4: $Edat_{ij} = time_{is} + D_{is} + T_{ij}$
5: $Ldat_{ij} = \beta_k - T_{if} - D_{js}$
6: $BI_{js} = \max\{a_j, Edat_{ij}\}$
7: $BS_{js} = \min\{b_j, Ldat_{ij}\}$
8: *if* $(Edat_{ij} \le b_j)$ *and* $(Ldat_{ij} \ge Edat_{ij})$ *and* $(BI_{js} \le time_{js} \le BS_{js})$ *then*
9: $L_i = L_i \cup \{j\}$
10: $CltRest = CltRest \setminus \{j\}$
11: *end if*
12: *Return* L_i
13: *end*

D. Sequential Construction Approach:

The general structure of this heuristic is given in algorithm (2). In this first approach, the tours are built entirely one after the other for each available vehicle at the initial depot, as long as none of the following stop conditions are met:

- All customers are inserted;
- All vehicle tours are saturated due to time constraints.

Algorithm 2. Sequetial Approach: HCS

1: *Tour* : *Tours to built*
2: *NbCustomers : Number of customers*
3: *NbVehicles : Number of vehicles*
4: *NbServices : Nymber of services*
5: *NbCustomersRes = NbCustomers* // *Number of customers not yet inserted*
6: *NbVehiclesRes = NbVehicles*
7: *While* (*NbVehiclesRes* ≠ 0) *et* (*NbCustomersRes* ≠ 0) *Do*
8: *Choose a vehicle k available*
9: $Tour_k \leftarrow \phi$
10: *Mark k as not available*
11: *NbVehiclesRes = NbVehiculesRes* – 1
12: $tstart_k = \alpha_k$
13: $treturn_k = 0$
14: $pos_k = d$ *// initial deposit*
15: $insert(d, tour_k)$
16: $s =$ *service offered by k*
17: *While* $CL \neq 0$ and (*NbVehiclesRe* ≠ *0*) *Do*
18: $CL = ConstructionCandidats(pos_k, k, s)$
19: $i = Random(CL, n_p)$
//Random selection among the n_p candidats of CL sorted according to one of criteria
20: *if* $(i \neq 0)$ then
21: $time_{is} = BI_{is}$
22: $pos_i = i$
23: *if i (is synchronised) then*
24: $\forall (s' \in S_i)\ time_{is'} = time_{is} + gap_{iss'}$
25: *end if*
26: $insert(i, Tour_k)$
27: *NbCostomersRes = NbCostomersRes* – 1
28: *end if*
29: *end while*
30: $tretour_k = time_{pos_k s} + D_{pos_k s} + T_{pos_k f}$
31: $insert(f, Tour_k)$
32: *End while*

E. Parallel Construction Approach.

Contrary to the previous version, in the parallel approach, a tour is initialized for each vehicle from the initial depot. Then, the list of customers reachable from the last customer inserted in the current tour is constructed. Insertion continues in parallel, as long as none of the stopping criteria mentioned above are met. The idea is to build the

tours simultaneously to avoid favoring one vehicle over another. The general structure of this heuristic is given in algorithm (3)."

Algorithm 3. Parallel Approach : HCP

1: *Tour* : *Tour to built.*
2: *NbCustomers : Number of customers*
3: *NbV ehicules : Number of vehicles*
4: *NbServices : Number of services*
5: *NbCustomersRes = NbCustomers* // *Number of customers yet inserted*
6: *NbVehiclesRes = NbVehicules* // *Number of available vehicles*
7: *SatureT = faux*
8: *While* (*NbCustomersRes* ≠ 0) or (*SatureT=true) Do*
9: *For* $k = 1$ *to NbVehicles Do*
10: *if* (k *is available) then*
11: $Tour_k \leftarrow \phi$
12: $tstart_k = \alpha_k$
13: $pos_k = d$ *// initial deposit*
14: $Tour_k \leftarrow Tour_k \cup \{d\}$
15: *Mark* k *as not available*
16: *NbVehiclesRes = NbVehiculeRes* – 1
17: *end if*
18: $s = service\ offered\ by\ k$
19: $CL = ConstructionCandidats\ (pos_k, k, s)$
20: $i = Random(CL, n_p)$
// *Random selection among the* n_p *candidats of CL sorted according to one of criteria*
21: *if* $i \neq 0$ *then*
22: $time_{is} = BI_{is}$
23: $pos_k = i$
24: $Tour_k \leftarrow Tour_k \cup \{i\}$
25: *NbCustomersRes = NbCustomersRes* – 1
26: *if* (i is synchronized) *then*
27: $\forall (s' \in S_i)\ \ time_{is'} = time_{is} + gap_{iss'}$
28: *end if*
29: $tretour_k = time_{pos_k s} + D_{pos_k s} + T_{pos_k f}$
30: *else*
31: *SatureT=true*
32: $Tour_k \leftarrow Tour_k \cup \{f\}$
33: *end if*
34: *End for*
35: *end while*

F. The repair procedure

Preliminary experiments of construction heuristics (2 and 3) often reveal unsatisfied demands (unassigned customers), and the stopping criterion is not only (*NbCustomersRes=0*) due to time windows. However, a repair procedure can be applied to the obtained solution to complete the insertion of remaining customers.

Let R be a solution obtained by one of the proposed heuristics, NL represents the list of customers not belonging to R . Let $i \in NL$ be a customer requesting service s . The repair process consists, firstly, of going through the tours constructed by the vehicles offering the service s and inserting these customers in the first possible position. In order to maximize the chances of inserting each customer, they are considered in increasing order of the start time of the time window.

However, if the solution is still not feasible at the end of this step, a second repair approach is then initiated on a neighboring solution. The latter is obtained by applying a perturbation to the current solution. This involves removing a certain number c_{max} of randomly chosen customers and inserting them in other possible positions to obtain a "neighboring" solution to the previous one. Thus, we retry the first part of the repair on the obtained solution. Here, one customer is removed, once a customer is randomly chosen, it is removed from its current position and reinserted into another position if possible. Otherwise, it is considered as not assigned.

After preliminary testing, it was found that the process consisting of "construction + repair" sometimes does not result in a feasible solution.

That is why, we propose to repeat the process of (construction + repair) until a feasible solution is constructed. Therefore, in order to produce different solutions each time, these heuristics have been randomized. The randomization is based on the list of candidate customers, and it consists of randomly choosing a customer among the n_p first candidates on the list (CL) sorted according to one of the criteria mentioned before. This list is therefore restricted and will be called the Restricted Candidate List (RCL) .

VI. Local search resolution

For vehicle routing problems, local search procedures or exploration strategies consist of improving the tours generated by a constructive heuristic by exchanging edges and/or nodes (called movements) in order to obtain higher quality tours. The solution obtained after applying such a transformation to a solution Sol is called a neighbor of the latter. The most well-known movements for routing problems concern the movements and/or permutations of nodes.

To improve the quality of the solutions obtained by the proposed heuristics for solving the VRPTW-SP, five movements are developed here. These movements involve one or several customers and/or tours. Of course, each movement is only accepted when it leads to a feasible solution with lower cost.

S_Relocate : The "move" operation involves moving a customer from its current position to another position within the same tour.

S_Exchange : This move swaps the positions of two customers within the same tour.

M_Relocate : Moves a customer from its current position to another position in another tour.

M_Exchange : This operation swaps the positions of two customers belonging to two different tours.

$2Opt^*$: Two edges from two different tours are deleted and replaced with two new edges. Each type of movement k defines a neighborhood N_k .

These local search movements can follow different exploration strategies. For example, when a given movement is examined, one can choose to keep the first one improving the current solution ("First improvement") or to generate the entire neighborhood and keep the best neighbor encountered ("Best improvement"). The question is to find a good compromise between the size of the neighborhood and the quality of the solutions obtained.

The local search movements that we propose come from classical vehicle routing problems, but their adaptation to the VRPTW-SP requires an evaluation in terms of cost and feasibility, which can be time-consuming. Moreover, and particularly for this problem, some movements are not promising and lead to infeasible solutions, they should be quickly rejected because of synchronization constraints and time windows. Therefore, preliminary tests have shown that searching for the best neighborhood requires much more time without a real overall improvement of the solution compared to a strategy that retains the first improvement. The latter is therefore chosen..

A. Descent strategies

We propose in this section of the article two descent strategies:

B. Random Neifgborhood Descent:

During the descent with random neighborhood strategy, the solution space is iteratively explored by visiting the different pre-defined neighborhoods in a random order to search a better quality solution. Before the exploration starts, a list Θ_{max} of movements is randomly generated (Θ_{max} corresponds to the number of proposed movements, i.e., 5). This order is maintained throughout the procedure. Each neighborhood is fully explored one after the other, and the local search stops when no further improvement is possible (see Algorithm 4).

Algorithm 4. Random neighborhood descent: DVA

1: *Sol* : *Initial Solution*
2: *List : list of randomly generated neighbourhood indexes*
3: *no_Improve = false*
4: *While* (*no_Improve≠ true*) *do*
5: *no_Improve = true*
6: $i = 1$
7: *While* $(i \prec \Theta_{max})$ *do*
8: $\delta = List[i]$
9: $Sol^* \leftarrow N_\delta(Sol)$
10: *if* $(F(Sol^*) \prec F(Sol))$ *then*
11: $Sol \leftarrow S^*$
12: *no_Improve* ← *false*
13: *else*
14: $i = i + 1$
15: *end if*
16: *end while*
17: *end while*

C. Variable neighborhood descent:

A given movement is repeated as many times as possible (as long as an improvement is obtained), and the next movement is introduced otherwise. It is assumed that an improvement during the exploration of N_δ (representing the neighborhood obtained by applying the movement δ) may create new changes in $N_1,.....,N_{\delta-1}$, which is why after any improvement, i is reset to 1. This strategy is useful when the movements that are less time-consuming (because they are less complex) are introduced first. Indeed, in this approach, the movements are considered in the order given in section 5 (see Algorithm 5).

Algorithm 5. Variable neighbourhood descent: VND

1: S : *Initial Solution*
2: $\delta \leftarrow 1$
3: *While* $(\delta \prec \Theta_{max})$ *do*
4: $Sol^* \leftarrow N_\theta(Sol)$
5: *if* $(F(Sol^*) \prec F(Sol))$ *then*
6: $Sol \leftarrow Sol^*$
7: $\delta \leftarrow 1$
8: *else*
9: $\delta \leftarrow \delta + 1$
10: *end if*
11: *End while*

The evaluation of each of these movements must be preceded by a feasibility test of time windows, synchronization constraints. Indeed, the insertion of a customer into a tour with n customers results in the rescheduling of the start service times of the following customers, which generates complexity in $O(n)$ in the worst case, if no technique is used to efficiently check the feasibility of the insertion. We propose in what follows a generalization of the techniques described by Kindervater & Savelsbergh (1997), which have been effectively applied to problems of tours with time windows."

D. Feasibility tests

These tests proposed by Kindervater and Savelsbergh (1997) allow to verify compliance with temporal constraints in the new solution. In our case, for a customer to be inserted into the tour, the start time of service for the following customers must be compatible with the corresponding time windows and synchronization constraints. This particularity is highlighted by Afif and al. (2013).

Let $Tour_k = (d, R_1, ..., R_i, ..., R_r, f)$ be a tour visiting r customers carried out by vehicle v, and let $Ttot_{R_i s}$ *and* $Ttard_{R_i s}$ be the earliest (or latest) departure time of customer R_i requesting service s , a_{R_i} (b_{R_i}) represents the start (end) time of the time window of customer i , so $T_{R_i R_j}$ corresponds to the duration between customer R_i and customer

R_j , and $D_{R_i s}$ corresponds to the service time of customer s requested by customer R_i where R_{i+1} denotes the successor of customer R_i in this tour. At each insertion, we have:

$$Ttot_{R_i s} = min(a_{R_i}, Ttot_{R_{i-1} s} + D_{R_{i-1} s} + T_{R_{i-1} R_i})$$

$$Ttard_{R_i s} = max(b_{R_i}, Ttard_{R_{i+1} s} - T_{R_i R_{i+1}} - D_{R_i s})$$

Clearly, there is a dependency between the tours, customers requesting two different services s and s' are synchronized, and the synchronized customer can be inserted into the tour of vehicle k knowing that it has already been visited by vehicle k' for another service s'. Note that these tests for the VRPTW are maintained for all customers."

VII. Results and Discussion

The linear model from Section 3.2 is translated into the Opl Studio modeling language and solved using the Cplex 12.5 linear solver. The heuristics and local searches proposed in this section were coded in C and executed on a computer running Linux."

The numerical evaluation was conducted on a set of 37 instances initially designed by Bredström & Rönnqvist (2007) for home healthcare routing problems with simultaneous synchronization. These instances include most of the specific characteristics of the VRPTW-SP, such as time windows, synchronization, preferences, etc., but are extended to meet the specifications of our problem, specifically the types of services (requested by customers and/or offered by vehicles) that are randomly generated. Thus, in our case, two types of synchronization are studied (simultaneous and precedence) and are randomly generated.

The benchmark is divided into 3 groups of different sizes, distinguished by the number of customers and vehicles used. The first group (G1) contains 14 instances with 18 customers and 4 vehicles, the second group (G2) contains 13 instances with 45 customers and 10 vehicles, and the third group (G3) contains 10 instances with 73 customers and 16 vehicles. In each group, the number of customers to be synchronized varies from two to five (which represents about 10% of the total number of customers, which is consistent with the synchronization rate generally encountered in home care structures). The size of the time windows relative to customers also varies: they can be small (r), medium (m) or large (l). Each instance is named as follows: $n - m - t - nb$ where n indicates the number of customers ($n \in \{18, 45, 73\}$), m the number of available vehicles ($m \in \{4, 10, 16\}$), t represents the width of the time window relative to customers $t \in \{r, m, l\}$, and nb indicates the number of customers to be synchronized ($nb \in \{2, .., 5\}$).

The results obtained by Cplex are first presented, followed by those obtained by the two heuristics (each tested for the 3 candidate selection criteria) improved by local searches. We show below the results of 12 evaluations denoted as follows: $A - B - C$, where $A \in \{P, S\}$ (P for the parallel heuristic and S for the sequential heuristic), B corresponds to the type of descent to be performed $B \in \{DVA, VND\}$ (DVA : for a descent with random neighborhood and VND : for a descent with variable neighborhood). Finally, C ($C \in \{1, 2, 3\}$) corresponds to the selection criteria mentioned in the previous section 4.2.

The aim of these tests is to measure the improvement brought by each local search on the proposed heuristics, in order to choose the best one. To evaluate the stability of the tested methods, it is interesting to perform multiple runs and report the best obtained value. For this purpose, all evaluations were launched on 10 independent runs. The parameters used for the heuristics to obtain the presented results are as follows: $n_p = 3$ for the size of the candidate customers list and $c_{max} = 2$ for the

number of customers to remove in the repair phase. They were chosen after preliminary tests to achieve a good computation time and solution quality. Finally, the resolution time of the Cplex linear solver was set to 3600 seconds.

VIII. Discussions

Table 1 presents the detailed results of the solutions obtained by Cplex on the 37 instances. Column 1 corresponds to the instance name, column *UB* corresponds to the upper bound (the value of the objective function) given by the Cplex solver (the symbol ∗ indicates that the corresponding solution is optimal), *Depl* and *Pref* correspond to the value of each term of the optimized objective function (*Depl* for the displacement criterion and *Pref* for the non preference criterion), *LB* gives the lower bound given by Cplex, column *Tps* reports in seconds the computation time required to obtain this solution, and finally, column *E* gives the relative gap in percentage between the upper and lower bounds. For each group, the average of the gaps and CPU times, the average over all instances solved by Cplex, and finally, the average over all instances tested are reported.

Table 1 – Results of Cplex for the 37 instances.

instances	*PLME*					
	UB	*Depl*	*Pref*	*LB*	*Cpu*	*E*
18-4-s-2a	40,13*	108,30	-68,17	40,13*	0,14	0,00
18-4-s-2b	81,15*	130,50	-49,35	81,15*	0,22	0,00
18-4-s-2c	34,78*	104,10	-69,32	34,78*	0,25	0,00
18-4-s-2d	55,26*	123,00	-67,74	55,26*	1,58	0,00
18-4-m-2a	57,42*	108,90	-51,48	57,42*	0,43	0,00
18-4-m-2b	21,31*	97,80	-76,49	21,31 *	0,17	0,00
18-4-m-2c	49,68*	128,40	-78,72	49,68*	17,38	0,00
18-4-m-2d	51,27*	128,70	-77,43	51,27*	1,47	0,00
18-4-m-2e	36,39*	102,90	-66,51	36,39*	0,61	0,00
18-4-l-2a	18,14*	86,40	-68,26	18,14*	10,67	0,00
18-4-l-2b	4,91*	92,70	-87,79	4,91*	2,16	0,00
18-4-l-2c	27,39*	107,10	-79,71	27,39*	529,34	0,00
18-4-l-2d	44,91*	96,60	-51,69	44,91*	629,50	0,00
18-4-l-2e	9,78*	78,00	-68,22	9,78*	0,34	0,00
*Avrg*1	-	-	-	-	85,31	0,00
45-10-s-3a	-82,01*	268,20	-350,21	-82,01*	17,07	0,00
45-10-s-2a	-37,79*	231,30	-269,09	-37,79*	16,79	0,00
45-10-s-3b	-35,74*	241,20	-276,94	-35,74*	15,38	0,00
45-10-s-2b	-97,42*	256,50	-353,92	-97,42*	1512,76	0,00
45-10-s-3c	-97,13*	264,30	-361,43	-97,13*	2433,61	0,00
45-10-m-4	-96,97*	270,60	-367,57	-96,97*	2658,89	0,00
45-10-m-2a	-43,10*	243,30	-286,40	-43,10 *	1066,90	0,00
45-10-m-2b	-120,65*	249,00	-369,65	-120,65*	2265,34	0,00

45-10-m-3	-124,06*	234,60	-358,66	-124,06*	1588,07	0,00
45-10-l-2a	-105,33	213,9	-319,23	-115,01	3601,11	8,42
45-10-l-2b	-147,14	212,4	-359,54	-157,3	3602,23	6,46
45-10-l-3	-150,53	220,2	-370,73	-162,18	3600,29	7,18
45-10-l-4	-152,48	221,4	-373,88	-165,55	3639,09	7,89
AvrG2	-	-	-	-	2001,35	2,30
73-16-s-2a	-195,82	369,3	-565,19	-231,36	3601,00	15,36
73-16-s-3	-187,45	351,9	-539,35	-234,52	3600,22	20,07
73-16-s-2b	-195,82	369,3	-565,197962	-231,36	3601,37	15,36
73-16-m-3a	-187,45	351,9	-539,35	-234,57	3600,81	20,09
73-16-m-2	-	-	-	-255,89	3600,60	-
73-16-m-3b	-145,38	386,1	-531,48	-258,94	3601,16	43,86
73-16-l-2	-	-	-	-319,76	3600,00	-
73-16-l-3	-	-	-	-325,19	3600,00	-
73-16-l-4	-	-	-	-333,82	3600,00	-
73-16-l-5	-	-	-	-339,51	3600,00	-
AvrG3	-	-	-	-	3600,86	22,95
AvrGBS	-	-	-	-	1413,01	4,52
Average	-	-	-	-	1479,30	4,52

Opl Studio found 23 optimal solutions out of the 37 instances, including all instances in the first group (G1), 9 instances in the second group (G2), and 0 instances in the third group (G3). For this last group, only 5 out of 10 instances were solved by Cplex. On average, and in comparison to the lower bounds, Cplex achieves a gap of 0% on the small instances (G1) within a reasonable computation time (85.31 seconds) and a gap of 2.31% for the medium-sized instances (G2) within a relatively high computation time (2001.35 seconds). Finally, for the last group of instances, Cplex achieves a gap of 22.95% within 3600 seconds. On average, over all instances that could be solved, Cplex achieves a gap of 4.52% within 1413 seconds and potentially the same gap over all instances within 1479.30 seconds.

For the 37 tested instances, tables (2 - 5) summarize the results obtained for each of the previously introduced evaluations (a summary table for the 3 selection criteria). Of the 10 executions performed, the best solution in terms of cost is selected. The evaluated results are those obtained at the end of the local search, although in the detailed tables, heuristic results are also presented. The selected performance indicators are (on average over all instances): the percentage gap from the lower bound (E_{LB}) and the upper bound (E_{UB}) of Cplex, the percentage gap of each criterion separately (E_{Depl} et E_{Pref}) , and finally the computation time *Tps* reported in seconds. The average solutions for each instance group are given in Avr_{G1}, Avr_{G2}, and Avr_{G3}. Then, Avr_{GBS} corresponds for each method to the average over instances solved by Cplex (i.e. for which Cplex obtained an upper bound). Finally, *Average* gives all tested instances.

Table 2 – Summary of P-DVA evaluation results

	P-DVA-1					P-DVA-2					P-DVA-3				
	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}
Avr_{G1}	28.8	28.8	4.0	5.05	0.01	35.8	35.8	4.9	7.79	0.01	46.1	46.1	6.48	6.60	0.01
Avr_{G2}	4.54	38.4	1.7	5.76	0.19	42.2	40.2	0.4	7.16	0.21	47.2	45.1	3.54	6.38	0.14
Avr_{G3}	29.7	15.9	4.6	2.63	1.34	28.7	15.1	7.0	0.95	1.33	29.9	14.6	0.89	4.90	1.06
Avr_{GBS}	34.9	30.7	3.2	4.96	0.34	38.4	34.4	3.4	6.47	0.37	44.6	40.8	4.41	6.24	0.29
Average	33.2	30.7	3.2	4.96	0.43	36.2	34.4	3.4	6.47	0.44	42.1	40.8	4.41	6.24	0.34

For the first and second group of instances, all approaches take only a fraction of a second to construct a feasible solution and improve it through local search. However, local search takes a bit more time (up to 2.43 seconds) to improve the constructed solution for the third group of instances. We can also observe that random local search is faster than variable neighborhood search (taking only half the time), and this is true for all evaluations.

Table 3 – Summary of P-VND evaluation results

	P-VND-1					P-VND-2					P-VND-3				
	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}
Avr_{G1}	100.	100.	10.	14.5	0.01	81.8	81.8	11.5	11.1	0.01	87.6	87.6	7.62	14.7	0.01
Avr_{G2}	67.9	66.0	1.9	12.5	0.15	65.1	63.1	7.36	8.04	0.16	95.3	93.3	5.78	13.3	0.14
Avr_{G3}	39.2	26.3	5.6	5.5	2.33	35.7	23.1	3.85	5.52	2.02	34.5	10.6	1.72	2.01	1.99
Avr_{GBS}	77.5	74.9	6.0	12.3	0.67	67.9	65.1	8.64	9.01	0.60	82.2	77.2	6.15	12.2	0.54
Average	72.5	74.9	6.0	12.3	0.69	63.5	65.1	8.64	9.01	0.61	75.9	68.8	5.38	10.8	0.59

The first remarkable element in these results is the importance of the initial solution construction strategy. Indeed, the parallel construction heuristic seems to be better than the sequential one, with an average gap of 33% compared to the lower bound.

Thus, we can distinguish the selection criterion *Ci*, which is related to the priority considered in the choice of the customer to be inserted during the construction phase (in increasing order of the earliest start times), as the best selection criterion.

Table 4 – Summary of the results of S-DVA evaluation

	S-DVA-1					S-DVA-2					S-DVA-3				
	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}
Avr_{G1}	33.4	33.4	3.3	6.0	0.01	28.8	28.8	4.61	6.1	0.01	42.11	49.6	7.05	4.56	0.01
Avr_{G2}	48.1	46.0	1.7	7.4	0.15	49.6	47.6	3.70	6.1	0.16	41.49	39.4	-0.70	8.68	0.14
Avr_{G3}	33.3	24.5	5.9	4.7	1.15	30.7	16.2	3.22	3.0	1.08	30.77	16.3	4.52	3.09	1.32
Avr_{GBS}	40.6	37.1	3.0	6.4	0.30	38.5	34.4	4.02	5.7	0.28	14.10	40.2	3.50	6.00	0.36
Average	38.5	37.1	3.0	6.4	0.37	36.6	34.4	4.02	5.7	0.35	38.83	40.2	3.50	6.00	0.41

The second notable observation to make concerns the strategy for exploring local search movements. Indeed, for both heuristics, random descent is found to be more effective on these instances than variable neighborhood descent. Finally, we can generally deduce that the best performances are achieved by the parallel construction heuristic when it is improved by a local search following a random descent. This conclusion is justified in terms of the average gap to the lower bound.

Although random local search seems to have better results when applied to sequentially constructed solutions, the lowest gap it achieves is 41.42 (S-VND-3), which is still higher than the gap obtained by P-DVA-1.

Table 5 – Summary of the results of the S-VND evaluation

	S-VND-1					S-VND-2					S-VND-3				
	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}	E_{LB}	E_{UB}	E_{Depl}	E_{Pref}	T_{ps}
Avr_{G1}	31.7	31.7	4.7	5.26	0.01	44.2	44.2	6.67	5.73	0.01	28.7	28.7	3.19	8.34	0.01
Avr_{G2}	60.6	58.8	3.1	10.1	0.17	66.1	64.4	3.10	11.06	0.23	58.7	56.9	3.81	9.14	0.23
Avr_{G3}	30.8	12.5	3.2	2.64	1.94	36.0	27.9	5.12	6.47	2.27	36.6	24.3	4.30	5.67	2.43

Avr_{GBS}	43.8	39.7	3.8	6.82	0.51	53.1	49.9	4.98	8.01	0.65	43.1	39.5	3.62	8.25	0.71
Average	41.6	39.7	3.8	6.82	0.59	49.7	49.9	4.98	8.01	0.70	41.4	39.5	3.62	8.25	0.74

IX. Conclusion

The mathematical formulation of the VRPTW-SP studied in this article is proposed. Two construction heuristics, each executed for three different selection criteria and based on the nearest neighbor principle, as well as two descent strategies are developed. Several combinations of the introduced methods were compared and the best configuration was distinguished.

The VRPTW-SP studied here is NP-hard, as it is a generalization of the VRPTW. When the size of the vehicle fleet is limited, the problem of finding a feasible solution is NP-hard. Moreover, the synchronization/precedence constraints generate interdependence between multiple tours. These temporal characteristics require non-trivial adaptations of heuristics and local searches known for vehicle routing problems.

The resulting linear model appears to be appropriate for the specifications of the proposed problem, optimally solving 23 out of 37 instances. However, the computation time increases considerably depending on the size of the instances, the width of the time windows, and the number of customers subject to synchronization constraints. Thus, the idea of avoiding duplication of synchronized nodes proves to be effective, compared to the results obtained in the same context other researchers where the model only optimally solves small instances.

The results obtained by the different approximate methods allow us to discern the difficulty of the problem. To achieve good results, the tour construction strategy is crucial and impacts both the feasibility and the quality of the solutions constructed. The parallel heuristic improved by a local search following a random neighborhood descent gave the lowest deviation from the best known solution.

In our opinion, the key point of the effectiveness of these methods lies in the adaptation of local search movements to synchronization constraints: the application of movements for all types of customers (synchronized or not), unlike most problems treated in the literature, where only movements involving unsynchronized customers are usually tested. Indeed, in general, local search is not performed on synchronized customers or, when a visit time for a first service is assigned, the visit time for the second service is systematically fixed. In our case, feasibility tests allow us to freely modify the visit time of synchronized customers while respecting the synchronization constraints. The best results were obtained by the parallel heuristic followed by a random descent local search. This version will be mostly reused later.

The proposed methods allow solving the proposed problem in a few seconds, which is crucial for this type of particularly complex problem. However, observations made on the solutions obtained by heuristics followed by a local search reveal the limits of these simple descent methods. The developed algorithms are effective, but the significant gap compared to the lower bounds of Cplex suggests that there is room for improvement if we turn to more sophisticated methods.

X. References

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