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OPTIMAL CUT ORDER PLANNING SOLUTIONS USING HEURISTIC AND META-HEURISTIC ALGORITHMS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Cut order planning is a significant task in the apparel industry which determines the fabric spreading layout that can affect different aspects of the apparel industry including the cost of garments, the efficiency of the sewing line, etc. Due to the nature of the cut order problem, it is very hard to determine an optimal solution for the cut order plan although there are ready-made software and also industry experts working on this. Hence, various attempts have been made to optimize it by using machine learning algorithms in the modern world. This review aims at identifying how heuristic and meta-heuristic algorithms are used to optimize the cut-order planning solutions to obtain a near-optimal solution. Furthermore, the lack of research limits it down to 13 papers to be reviewed, and this paper discusses the methodologies and algorithms used, research parameters, issues, and future areas that need to be investigated for the cut order problem. The review shows that the genetic algorithm is widely used to optimize the cut-order plans by adopting the hybridization approaches along with some other meta-heuristic algorithms such as simulated annealing, tabu search, etc. Experimental results indicate that researchers were able to minimize fabric waste by optimizing the cut order plans.

KEYWORDS: *heuristic algorithms, cut order problem, cut plan, meta-heuristics, systematic review, apparel industry*

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1. INTRODUCTION

The apparel industry is one of the leading industries possessing trillions of dollars in market capitalization. In general, the garment manufacturing process has different stages (Fig. 1). Cutting is the most important process in apparel manufacturing because a significant amount of garment cost depends on the fabrics and is the most valuable material in the production process (Enes et al., 2020).

Cut order planning and spreading comes before the cutting. Spreading is where the fabrics are laid on the cutting table before assigning the markers to them. Cut order plans are there to determine proper fabric spreading layouts. It describes how the fabric is going to be laid on the cutting table hence orders require large quantities of pieces at once. The cut order problem (COP) with the cutting process in the apparel industry is known to be an NP-Hard (nonlinear polynomial-time) problem (Unal et al., 2020). Not being able to have an optimal solution on how the fabric and markers are to be laid down on the cutting table to complete the order quantity by minimizing the fabric wastage can be known as COP (Jacobs-Blecha et al., 1998). Cut order planning may differ according to the objective preferred such as fabric utilization, and time efficiency. Manual labour by industry experts and industrial software programmes specified to generate cut order plans are currently being used to find optimal solutions.

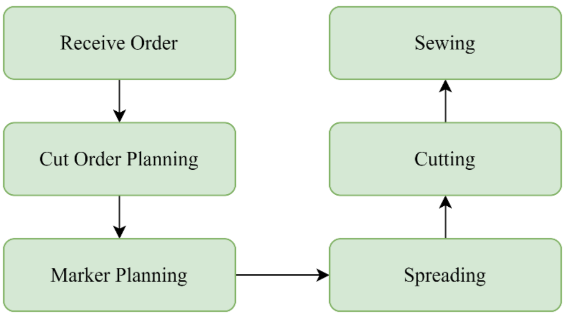


Figure 1: Garment manufacturing process

Statistics show that textiles waste will increase by 60% each year between 2015 and 2030, resulting additional 57 million tons of waste every year (Shirvanimoghaddam et al., 2020), (Niinimäki et al., 2020). So, the efficiency of traditional methods is questionable and hence, researchers attempted to try different approaches for the cut order problem using machine learning techniques that are more advanced than just a software programme (Schmidt et al., 2019). Lots of algorithms and methodologies can be found with machine learning. It seems that heuristic and meta-heuristic algorithms are more popular among researchers when it comes to problems like cut order planning that requires optimization (Poorzahedy et al., 2007).

This study aims at investigating how heuristic and meta-heuristic algorithms are used to optimize cut-order planning solutions. The review contains the following sections. Section 2 describes what motivated the authors to study this area. Section 3 investigates existing literature on COP. Section 4 describes the methodology used to conduct the review. Section 5 investigates the findings of the study. And finally, in section 6, research gaps in the current research are discussed, which will be useful for future researchers.

Objective of the study

As previously described, the objective of the cut order plan is to determine the fabric spreading layout on the cutting table when there is an order with a higher quantity and in different sizes, colours, etc. (Enes et al., 2020). In such a scenario, industry experts predetermine how the fabrics are spread over the cutting table to minimize the fabric amount required (Sarkar, 2007).

An optimistic cut order plan will reduce the single product cost by minimizing fabric wastage (Jana, 2007). Non-optimal cut order plan can lead to extra pieces of garments and the time required for the cutting process, labour cost, etc. depends on the cut order plan. Different types of automated software are available to generate cut order plans/solutions (Padhye, 2007) but their effectiveness is questionable.

Here is an example of an order that consists of 40 garments. Small 15 [Red 5, Blue 10], Medium 25 [Red 10, Blue 25]

Two possible COP solutions are given below for the particular order

Solution 1

Lay 1 – S:2M [5 Red, 5 Blue]
Lay 2 – S: M [5 Blue]

Solution 2

Lay 1 – S: M [5 Red, 10 Blue]
Lay 2 – M [5 Red, 5 Blue]

Each layer contains two lays and size combinations for each marker and supposed layers for each segment (lay). Figure 2 illustrates a single lay plan. Hence this is a simple example, it is possible to generate more suitable solutions that can reduce fabric wastage. With larger quantities of garments, it is difficult to have an optimal solution as a cut order plan.

Heuristic and meta-heuristic algorithms perform a significant role in these kinds of optimization problems (Rodríguez et al., 2018). Researchers tend to use both types of algorithms to address the cut-order planning problem by generating optimal cut-order planning solutions. But in the meantime, there is no critical understanding of them for the particular problem.

Different meta-heuristic algorithms were introduced over the decades (Hsieh, 2020) and many possible trends could be identified and could have developed for generating cut-order planning solutions.

There are some systematic reviews done but they mainly focus on strip packing problems and marker-making processes in the apparel industry. There is a lack of reviews focusing on the cut order planning process.

It will be more beneficial to have an understanding of how and what the meta-heuristics were used previously by the researchers to address the cut order problem. So, the objective of the study is to identify how researchers intended to use meta-heuristic algorithms to address the cut order planning problem.

Related Work

This section intends to discuss existing knowledge related to this area.

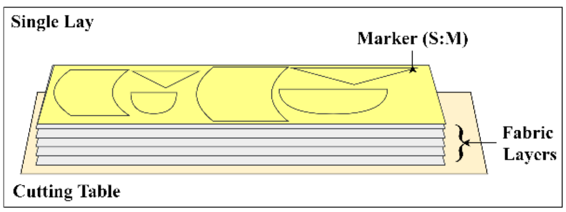


Figure 2: Fabric spreading layout

Guo et al. conducted a review to determine how artificial intelligence (AI) is applied to the apparel industry covering 4 areas which are design, manufacturing, retailing, and supply chain management (Guo et al., 2011). It covers most of the apparel manufacturing process. The authors determined that machine learning methodologies can improve the efficiency of the garment industry. Neural networks and genetic algorithms are the most popular among researchers according to the insights given. Cut order planning and marker making are considered a single problem that may not be the ideal situation within the apparel industry.

Jalil et al. conducted a systematic literature review to discuss the challenges facing the adoption of AI technologies in the garment industry (Jelil et al., 2018). The author classified the review into three categories to cover the areas: production planning, control, and scheduling. Cut order planning is discussed as an individual problem. It appears that genetic algorithms were used by the researchers to address the cut-order planning problem.

Table 1: Existing literature on cut order planning using heuristic and meta-heuristic algorithms

Title	Goal
Applications of artificial intelligence in the apparel industry: a review (Guo et al., 2011)	Analyze the limitation and research challenges of previous studies.
Review of Artificial Intelligence Applications in Garment Manufacturing (Jelil et al., 2020)	Investigate and exploit artificial intelligence techniques in a variety of industrial applications.
AI for Apparel Manufacturing in Big Data Era: A Focus on Cutting and Sewing (Xu et al., 2018)	Investigate how artificial intelligence is used in cutting, sewing, finishing, and packing processes.

Xu et al. investigated how artificial intelligence is being used in cutting and sewing processes in the apparel industry (Xu et al., 2018). Cut order planning is discussed as a separate task under the cutting process. It states that the thickness of the cloth and the depth of the cutting knife decide the maximum number of plies for the cut order plan. It further states that the time required for the cutting process can be affected by the cut order plan.

Findings show that there are no direct reviews done on this particular area. Hence there is a need for a systematic literature review to have a comprehensive view of how meta heuristic algorithms are being used to address the cut orer planning problem.

2. METHODOLOGY

The review is done using guidelines provided for performing systematic literature reviews in software engineering (Kitchenham et al., 2007). Research questions and inclusion and exclusion criteria are defined first and then reliable sources are identified to find relevant research papers.

For the conducting phase, search strings are used with the relevant keywords to search through the databases and retrieved the papers. Inclusion and exclusion criteria were applied to determine the most effective research papers and then the review task was done. Finally, for the reporting, the findings on the research questions are discussed below.

Planning the Review

This section describes how the review was planned, research questions and the inclusion and exclusion criteria.

Research questions

To find how meta-heuristic and heuristic algorithms were used in optimizing the cut-order planning solutions these research questions are defined.

RQ1 – What is the research trend of using heuristic and meta-heuristic algorithms in recent years?

RQ2 – Which algorithms are popular when addressing the cut order problem?

RQ3 – How effective are the parameters used by the researchers on the cut order problem?

RQ4 – What are the existing research issues and future areas that can be investigated?

Search strategy

Terms mentioned in the search criteria are used to search through the selected databases to find relevant papers on the focused field of study. The search strings were varying because the filtering and searching facilities given by the selected databases are different from each other.

IEEE Xplore, ACM Digital Library, Science Direct, SpringerLink, and Google Scholar were the selected databases in which papers that are published in English from the year 2007 to 2022 were sought for.

Then the inclusion and exclusion criteria were applied to the selected papers to refine them furthermore.

Search criteria

Search strings used and generated for each database are as follows. The best possible strings were selected to achieve maximum accuracy while searching.

IEEE Xplore – "Full Text & Metadata":cut order AND "Full Text & Metadata":plan OR "Full Text & Metadata":problem OR "Full Text & Metadata":planning AND "Full Text & AND "Full Text & Metadata":apparel OR "Full Text & Metadata":apparel industry AND "Full Text & Metadata":fabric OR "Full Text & Metadata":fabric utilization

ACM Digital Library – [[Title: cut order plan] OR [Title: cut order planning] OR [Title: cut order problem]] AND [Title: meta heuristic algorithm] AND [Title: fabric utilization apparel industry] AND [Publication Date: (01/01/2007 TO 12/31/2022)].

SpringerLink – 'cut AND order AND problem AND plan AND planning AND apparel AND fabric AND meta AND heuristic'.

ScienceDirect - cut order plan planning problem apparel industry fabric utilization meta-heuristic, cut order planning problem solutions apparel industry heuristic algorithm.

Google Scholar - cut order problem plan planning apparel fabric utilization meta-heuristic algorithm.

Inclusion and exclusion criteria

To be effective these inclusion and exclusion criteria are used to determine whether the paper must be included or not. The papers that fulfill these criteria are included in this review. Table 2 describes the criteria in detail.

Table 2: Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria	Justification
IC1: Papers Published between 2007 - 2022		Significance improvement can be determined hence the development of the meta-heuristics trendier these years.
IC2: Papers published in English		Resources are not enough to translate the papers and translation can lead to misunderstanding of the content.
IC3: Papers that are related to the apparel industry.		The literature review is intended to review the cut order problem that occurs in the apparel industry.
IC4: Papers relevant to the cut order planning		The literature review is focused on the cut order problem.
	EC1: Papers that are an abstract or a review or a case study.	The full paper needs to be analyzed to understand how researchers address the cut order problem.
	EC2: Publications that do not represent any heuristic or meta-heuristic algorithms.	Identifying how meta-heuristics are used to address the cut order problem is the aim of the study.

Conducting the Review

This section aims to describe the selection and data synthesis phase in detail.

Study search and selection

Selected databases were searched to find the relevant research papers using search strings defined.

The selection was done according to the flow diagram guidelines provided by the PRISMA statement (Page et al., 2021). Figure 3 illustrates the selection process.

Synthesis and data extraction

According to the methodology, the next part was data extraction and synthesis.

Extraction and synthesis were done by using "Zotero" which is a software programme that aids researchers to collect, organize, cite, and share research. Selected papers were imported into the programme and managed through it. An excel sheet was used to extract data from the research papers including title, abstract, year, authors, parameters used, meta-heuristic algorithms used, difficulties, and suggested future works.

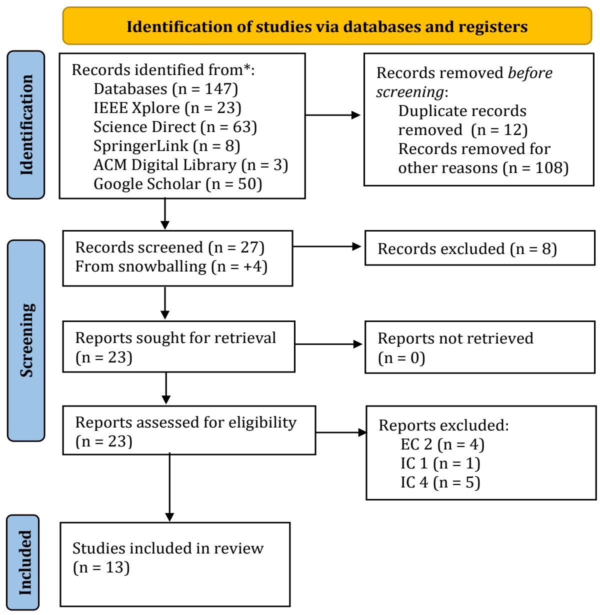


Figure 3: Selection of papers

3. RESULTS

This section contains the findings from the research by reviewing and previously defined research questions are answered here. A total of 13 research papers were identified that are relevant to the research topic satisfying the objective of this systematic literature review.

Research Trend (RQ1)

According to the conducted review, the information about retrieved papers includes where they have been retrieved and when they have been published (Table 3). illustrates the distribution of research attempts taken over the years. The current trend lacks the interest of the researchers to optimize the cut order planning problem (COP) using heuristic and meta-heuristic algorithms considering the number of research works done.

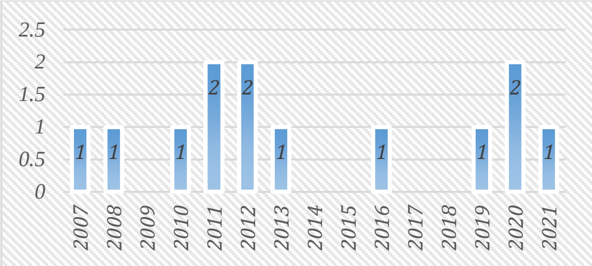
Table 3: Information on selected papers

ID	Venue	Title	Summary
#1	Springer-Verlag Berlin Heidelberg	A hybrid genetic algorithm for the cut order planning problem (Bouziri et al., 2007)	A hybrid approach to generate cut order plans using genetic algorithm, and simulated annealing
#2	International Journal of Production Economics	Genetic optimization of fabric utilization in apparel manufacturing (Wong et al., 2008)	A genetically optimized decision-making model
#3	International Journal of Production Economics	A state-space solution search method for apparel industry spreading and cutting (Nascimento et al., 2010)	Graph theory-based model with heuristic algorithms
#4	Springer-Verlag Berlin Heidelberg	Research on cut order planning for apparel mass customization (Yan-mei et al., 2011)	Mathematical model optimized by probability search algorithm and genetic algorithm.
#5	Production Planning & Control	Elucidating a layout problem in the fashion industry by using an ant optimisation approach (Yang et al., 2011)	Integer programming model using ant colony optimization algorithm.
#6	Journal of Emerging Trends in Computing and Information Sciences	Canonical genetic algorithm to optimize cut order plan solutions in apparel manufacturing (Abeysooriya et al., 2012)	A canonical genetic algorithm approach
#7	International Journal of Information and Communication Technology Research	Hybrid approach to optimize cut order plan solutions in apparel manufacturing (Abeysooriya et al., 2012)	A hybrid approach using the genetic algorithm
#8	Elsevier	Optimizing cut order planning in apparel production using evolutionary strategies (Wong et al., 2013)	Decision-making model optimized by genetic algorithm
#9	International Transactions In Operational Research	Heuristics for the combined cut order planning two-dimensional layout problem in the apparel industry (M'Hallah et al., 2016)	Comparative research based on simulated annealing, genetic algorithm, and hybridization of them
#10	IEEE/CAA Journal of Automatica Sinica	A heuristic algorithm for the fabric spreading and cutting problem in apparel factories (Shang et al., 2019)	An iterated greedy algorithm-based model using heuristic algorithms
#11	Computers & Industrial Engineering	Hybrid heuristics for the cut ordering planning problem in apparel industry (Xu et al., 2020)	An approach using integer programming, genetic algorithm, and enumerate algorithm.
#12	The Journal of The Textile Institute	Reducing waste in garment factories by intelligent planning of optimal cutting orders (Tsao et al., 2020)	A comparative approach based on genetic algorithm, simulated annealing, tabu search, and hybridization of them
#13	The International Journal of Advanced Manufacturing Technology	Optimization of garment sizing and cutting order planning in the context of mass customization (Alsamarah et al., 2021)	Genetic algorithm-based approach aligned with heuristic algorithms

According to what we have found, there are not many attempts to address the cut order planning problem using meta-heuristic algorithms and only a few researchers were interested in this particular problem.

Behalf of that marker planning optimization was considerably popular among the researchers. Fig. 4

According to the review, researchers used several heuristics, metaheuristic algorithms, and hybridized versions of them to generate solutions to the cut order



. **Figure 4: Distribution of research works**

Methodology and Algorithms Used (RQ2)

planning problem.

Bouziri et al. proposed a hybrid approach to generate cut-order planning solutions by combining two-dimensional layout problems and cut-order problems (Bouziri et al., 2007). The resulting problem is modeled and solved using a hybrid heuristic that combines a genetic algorithm (GA) and simulated annealing (SA).

Wong et al. created a genetically optimized decision-making model using adaptive evolutionary strategies to address the cut-order planning process (Wong et al., 2008). Genetic algorithms are used to optimize the COP decision-making model and are further optimized using an evolutionary algorithm (EA) with the evolutionary trajectories.

Nascimento et al. researched to determine optimal fabric spreading and cutting schedules. A graph theory-based model was developed by ed applying heuristic rules to select the most promising colour combination (Nascimento et al., 2010). Further applied exhaustive search algorithms (ESA) and greedy search algorithms (GSA) to achieve suitable solutions in the hybrid phase.

Yan-mei et al. developed a mathematical model and optimized it by using a probability search algorithm (PSA) to obtain optimized size combination plans (Yan-mei et al., 2011).

Yang et al. proposed a model combining an integer programming model (IP) and ant colony optimization (ACO) to identify most economic cutting patterns to control cost and reduce production time (Yang et al., 2011).

Abesooriya et al. carried out research based on a pure genetic algorithm to optimize cut order problems to find the optimum size ratios for each cut template used (Abeysooriya et al., 2012). Methodology breaks down into 3 stages that are encoding chromosomes, selection, crossover, and mutation.

Abesooriya et al. used a hybrid approach to optimize cut-order plan solutions in apparel manufacturing. hybridization was done by combining the conventional heuristic of COP generation and genetic algorithm (GA) to optimize cut-order plan solutions targeting the reduction of the long execution time with the previous method (Abeysooriya et al., 2012). A mask encoding string was defined by them to improve the encoding mechanism of basic GA using the conventional heuristic method of COP generation in the process.

Wong et al. created a genetically optimized decision-making model using adaptive evolutionary strategies to optimize the cut order problem. model, then validated using 4 sets of real production data. Genetic algorithms are used to enhance the resulting cut-order plans (Wong et al., 2013).

M'Hallah et al. combined Cut order problem (COP) and two-dimensional layout (TDL) into a single problem CT (CT = COP + TDL) which objected to minimize fabric length and then it is solved using constructive heuristics, and three metaheuristics: simulated annealing, genetic algorithm, and hybrid approach (genetic annealing) (M'Hallah et al., 2016).

Shang et al. proposed an iterated greedy algorithm for solving the fabric spreading and cutting problem which contains a constructive procedure and an improving loop (Shang et al., 2019). With that, they create a set of lays in sequence first, and then the loop tries to pick each layer from the layer set and rearrange the remaining lays into a smaller lay set as much as possible.

Tsao et al. used a variety of hybrid heuristics with genetic algorithms to determine effective COP solutions (Tsao et al., 2020). They combined two heuristics in their study which are simulated annealing-based genetic algorithm (SA-GA) and tabu-search-based genetic algorithm (TS- GA) and compared three metaheuristics: simulated annealing, genetic algorithm, and tabu search simulated annealing, genetic algorithm, and tabu search by formulating COP problem as a mixed-integer programming model.

Figure 5: Algorithms used to optimize COP

Xu et al. presented a mass customization-oriented garment production planning system to generate more efficient size charts and cut order plans (Xu et al., 2020). A genetic algorithm and expanded integer programming model are developed to optimize the cut-order solutions.

Alsamarah et al. created a genetic algorithm-based approach to optimize the cut order planning which was designed depending on mathematical equations to get the correct distribution (Alsamarah et al., 2021).

Research Parameters Used to Optimize Cut Order Planning (RQ3)

In most cases, researchers focused on the fabric wastage factors to minimize the fabric wastage with the cut order planning. Minor of them considered other aspects as well.

The number of sizes, order quantities, fabric width, minimum and maximum ply height, the maximum length of the cutting table, and the shortest length layout of the pieces of particular sizes is taken into consideration by Bouziri et al. (Bouziri et al., 2007).

Wong et al. considered various factors affecting the cut order plan to conduct their research covering the fabric, fabric cost, labor cost, time constraints, and electricity requirements. (Wong et al., 2008). The same parameters were used again in the subsequent research of the authors (Wong et al., 2013).

Nascimento et al. used fabric utilization parameters such as Number of sizes, Number of colours, Maximum spreading length, etc., and cost factors including fabric cost, average sale price, etc. to maximize the efficiency of the output generated by the models (Nascimento et al., 2010).

Yan-mei et al. focused on the length of the cutter blade, the thickness of the fabric, the size of the clothes, and the cutting table to conduct their research (Yan-mei et al., 2011).

Yang et al. focused on fabric utilization factors such as a set of the patterns used, colours, demand for each size in a particular colour, etc., and cost factors such as stack cost of a layer of cloth, cutting pattern setup cost, etc. (Yang et al., 2011).

Abesooriya et al. in canonical genetic algorithm to optimize cut order plan solutions in apparel manufacturing considered the fabric measures such as the number of different fabric types, the number of sizes, the maximum number of garments in the cut template, the maximum number of plies in the lay (Abeysooriya et al., 2012).

Abesooriya et al., with their subsequent research considered fabric measures such as the number of garment sizes, the number of different fabric types, the maximum number of garments in the cut template, the maximum number of plies in the lay, and the number of times a particular size appeared in the cut template (Abeysooriya et al., 2012). The major goal was to reduce the execution time of the algorithm.

M’Hallah et al. considered the unique garment type and colour that is being laid on the table to determine the best possible option when cutting a huge number of quantities, number of occurrences of each size, the number of layers, and the length are some of the parameters mentioned (M’Hallah et al., 2016).

Shang et al. used parameters such as the maximum allowed fabric length, maximum allowed fabric layers, number of different garment figures, and number of different fabric types (Shang et al., 2019).

Tsao et al. objected to finding the optimal number of layers for the cut order plan by considering the number of ordered sizes and the demand for each size (Tsao et al., 2020). Here are the other parameters which they considered; Estimated length of fabric for size, cost of Setup a new section, cost of excess production, cost of using fabric, the maximum length of fabric, the maximum number of layers in each section, and the minimum number of layers in each section.

Xu et al. used a set of sizes, order demand for size, set of markers, set of markers, etc. to improve the fabric utilization when generating the COP solutions (Xu et al., 2020).

Alsamarah et al. investigated fabric utilization with a fixed marker width and marker length which is defined while fabric consumption (Alsamarah et al., 2021). Along with that, they considered the number of different sizes, colours, and the number of layers in the process.

Research Issues and Future Works (RQ4)

According to the researchers, the most common difficulty was to generate the near-optimal solution for the cut order planning problem because of its NP-Hard nature.

Bouziri et al. used outdated hardware resources compared to currently available hardware, and they state that "GAn and the sequential TDL algorithm are coded in Fortran and run on a Pentium IV, 1.7 GHz and 256 Mb of RAM" which could affect the execution time of the algorithm (Bouziri et al., 2007).

Shang et al. also used slightly outdated hardware resources which is a server with Intel Core2 Duo Q9400 2.66 GHz and Microsoft Windows 7 Ultimate (Shang et al., 2019).

Nascimento et al. state that because of the complex and combinational nature of the problem its size grows exponentially with time and hence processing time takes too long (Nascimento et al., 2010).

Yan-mei et al. only focused on single fabrics with different sizes when optimizing the cut order plan (Yan-mei et al., 2011). Hence, they state that future research could focus on more customized apparel orders and other optimization methods can also be used.

Yang et al. used minimal hardware resources which can affect the efficiency of the model developed (Yang et al., 2011). They used a PC with a 1.66 GHz Intel Core Duo L2400 and 1 GB RAM. Also, they state that sometimes the hybrid model that they have developed was unable to result in a good solution in some cases.

Abesooriya et al. state the original form of the genetic algorithm is unable to solve more complex COP problems. For example, it cannot obtain quality solutions in small population sizes or smaller numbers of generations (Abeysooriya et al., 2012). Hence, they suggested a hybrid approach in which the properties of GA will be used to optimize the solution and conventional heuristic methods of solving COP reduce the population size and number of generations which enables higher efficiency and greater effectiveness.

In their subsequent research, Abesooriya et al. state that further investigation using optimization techniques such as simulated annealing, and tabu search can be done to achieve more effective and efficient solutions for the COP when combined with the genetic algorithm (Abeysooriya et al., 2012).

Wong et al. state that the evolutionary process of cut order planning can be improved further by focusing on the combination of evolution strategies and other heuristic search techniques such as particle swarm optimization, ant colony optimization, etc. (Wong et al., 2013). which will improve the convergence speed and global optimization ability.

M'Hallah et al. said that future research can adopt other types of costs, multiple garments, and patterned fabric, and improve the TDL packing approach (M'Hallah et al., 2016).

It says that among all the algorithms the high-level setting always yielded a better result for the minimum cost but the CPU time was long Tsao et al. in their research (Tsao et al., 2020).

Xu et al. state that the research work can be improved by adding fit related pricing system to the sizing system and as per the COP, it is important to apply artificial intelligence techniques to generate accurate data of markers due to their complexity with the size combinations (Xu et al., 2020).

Alsamarah et al. say that their study can be extended to several sectors in garment factories, with multiple objectives integrating production line efficiency, reliability, and the extension of further research (Alsamarah et al., 2021).

4. DISCUSSION

This section discusses the research gap and areas that can be investigated in future work. The study shows that the number of research done on cut order planning problems by using heuristic and meta-heuristic algorithms is considerably less compared to other investigative areas.

As per the related work, existing literature reviews barely contain the involvement of meta-heuristic algorithms in the context of cut order planning. Covering the whole production process of the apparel industry tightened the space to investigate the cut order planning problem specifically throughout the empirical literature. It has been determined that the cut order problem can be addressed by using meta-heuristic algorithms but it lacks a direct focus on the cut order planning problem.

Hybridization of meta-heuristics allowed researchers to achieve better solutions to solve optimization problems. According to the literature, genetic algorithm (GA), simulated annealing (SA), tabu search (TS), evolutionary strategy (ES), and some other heuristics are used to achieve better results.

According to the review, it has been determined that for 77% percent of reviewed papers, researchers used genetic algorithms as one of their algorithms to optimize the cut-order solutions. 92% of researchers used some sort of hybridization approach with their research.

In recent years, many meta-heuristic algorithms have been introduced such as galactic swarm optimization (2015), duelist algorithm (2016), mayfly optimization algorithm (2020), etc. New heuristics can also be derived from the industrial activities that are currently used for the COP. Researchers can attempt to investigate them.

Primarily the fabric utilization factors are widely used to optimize the COP such as fabric height, width, ply height, number of fabric layers, etc. Industrial application of cut order planning requires several facts to be considered such as the objective function of the cut order plan (ex-cost, time), labour cost, electricity cost, etc. introducing such parameters based on those factors may increase the effectiveness and efficiency of the solutions resulting maximum output from the cut order plan. A thorough investigation of such factors can be done in future works.

It has been discovered that existing research needs some enhancement with the hardware resources that were being used. Hardware resources are rapidly growing with size, performance, etc. The impact of the hardware resources when using heuristics and meta-heuristic algorithms to optimize COP can also be investigated.

Thus far, the genetic algorithm is popular among researchers. Study shows that hybridization of the genetic algorithm combining heuristics or other meta-heuristic algorithms were given better solutions. Combining new algorithms with genetic algorithms may result differently. Considering the NP-hard nature of the cut order planning to achieve a near-optimal solution is still questionable hence the solutions can be further optimized by improving the models proposed by the researchers.

5. CONCLUSION

Cut order planning creates a problem where fabric wastage can happen when the cut plan is not optimal. Using traditional methods such as manual labour and industrial software cannot ensure optimal solutions for cut order planning. In that case, researchers investigated meta-heuristic algorithms and whether they can achieve near-optimal solutions for the cut order problem and found that they are more accurate and efficient than the traditional methods.

The study aimed at finding how heuristic and meta-heuristic algorithms are used to optimize the cut order problem to achieve optimal solutions to identify recent research trends, use of heuristics and algorithms, parameters being used, and current research issues and future perspectives. A total of 13 papers were selected to be reviewed and further analyzed to answer the research questions.

Results indicate that genetic algorithms and simulated annealing are mostly used by the researcher to optimize the particular problem. Hybrid approaches combining heuristics and meta-heuristic algorithms, especially the genetic algorithm resulted in more promising solutions.

Researchers primarily focused on fabric utilization factors enabling gaps in the investigation of cost factors and time constraints. Further improvement of the models, adaptation of new heuristics, and meta-heuristic algorithms may result in more optimal solutions for the cut order planning problem.

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