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Intelligent Computer-Aided resource planning and scheduling of machining operation

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Abstract

The article describes the possibility of application of computer on the process of planning and scheduling in Kosovo Enterprises. We have investigated job shop scheduling on the shop floor of the machining operation. Furthermore, particular attention is dedicated to the schedule activities in such a way to use equipment and all resources available in an efficient manner. For solving our problems, we have used the program package "LEKIN®" and Genetic Algorithm-GA for process planning and scheduling to demonstrate how planning and scheduling techniques will help Kosovo enterprises to optimize their processes.

Keywords: Genetic Algorithm; "LEKIN®" software; planning and scheduling; machining operation; Kosovo enterprises

1. Introduction

The process of manufacturing has developed and changed rapidly due to new technology and worldwide competition. To be a competitive in today market is a big challenge because needed quicker and faster development time for products to realize. Manufacturing technologies and things such as Concurrent Engineering, Just in Time Production, Design for Manufacturing, Big Data, IoT – Internet of Things, CPS – Cyber Physical Systems,

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CAD/CAPP/CAE/CAM etc. have pushed manufacturing further. Therefore, to reduce the time of production, companies should be able to produce their products in the quick manner with effective cost and with a quality [1][2].

From conceptualization to the final product a number of steps are involved, they include product design, process planning and scheduling, production system design, process control, and so on. Computers are used extensively in all these stages to make the entire process easier and faster. Contribution of computers in all these stages is very important, improved accuracy and quality, reduced costs and lead times, minimization errors and duplicated work, more efficient analysis tools, optimized processes, have an important role in accurate control and monitoring of the processes and machines, etc.

In this paper, we have investigated the application of computer on the process of planning and scheduling. Based on the investigation in field of CAD/CAM systems and ICT in Kosovo Enterprises (source: own study) [3][4], we have noticed that the application of CAD/CAM systems in Kosovo Enterprises is in low level. Based on the analyses of answers to questions of the questionnaire shows that, from 26 inspected companies and institutions, five of them are using CAD / CAM systems or 19.23%, 7 are partially using CAD / CAM systems, or 26.92% and 14 others have not yet introduced this technology in their organization or 53.84%.

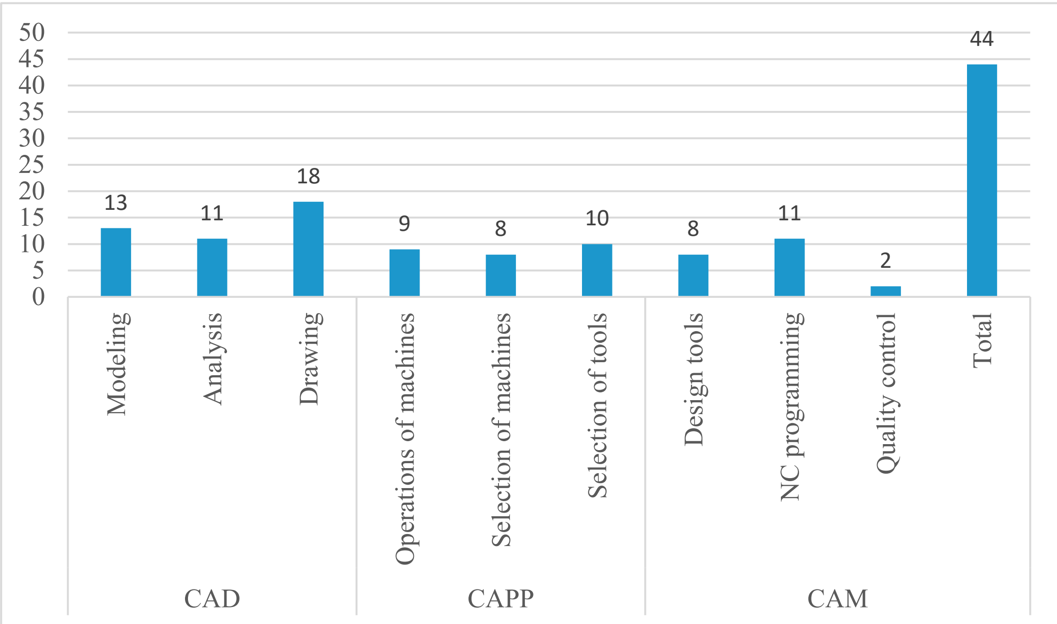

Fig. 1. Application of CAD / CAM systems according to the phases of processing through industrial enterprises [3]

Figure 1 above shows that CAPP – Computer Aided Process Planning is in the lower level of the application than CAD and CAM systems. Due to application of CAPP is in low level in the Kosovo Enterprises, we have investigated job schedule in shop floor of machining operation on parts. Therefore, is chosen the metalworking company for investigation the process of planning and scheduling. Furthermore, particular attention is dedicated to the schedule activities in such a way to use equipment and all resources available in an efficient manner.

2. Theoretical Background

2.1. Computer Aided Process Planning – CAPP

The computer aided process planning (CAPP) represents the methodology of process planning and scheduling in the software package. The CAPP includes all process planning activities needful to realize the design of the process plan. The role of CAPP system is to help the planning activities such as selection of operations in machines – job scheduling, machine selection, operations and cutting tools, process optimization, etc. Process planning and scheduling have a central function in manufacturing industries which consists in a systematic determination of the methods by which a product is to be manufactured competitively and economically [5]. Due to manual experience-based process planning and scheduling are usually characterized by lack of standardization, low level of optimization, long lead times and high costs, computer-aided process planning (CAPP) systems were developed to assist the planners in their activities [5],[6].

2.2. Process planning and scheduling

Manufacturing organizations exist to produce and supply products that customers need, at a price that they are willing to pay. Successful organizations achieve this aim while making a profit for their shareholders. There are very few organizations that exist in monopoly, and most have to compete in the open market. The product price is therefore determined by the competition, and the only way to increase profit is to reduce production and distribution costs. This means managing and operating the organization in an efficient manner. Production planning and scheduling are two important topics that serve to increase efficiency in manufacturing and improve effectiveness in customer service [7],[8].

Scheduling in its broadest sense is as old as mankind. Loosely defined, scheduling is an act of defining priority or arranging activities to meet certain requirements, constraints, or objectives. In olden days (and even now), time was (and still is) a major constraint. People schedule their activities so that jobs could be accomplished within the available time. For example, time to get up, time to work, time to play, time to sleep, and so on. Time was and still is, a limiting resource, and we need to schedule our activities, consciously or unconsciously, to utilize this limited resource in an optimum manner [7].

3. Methodology

Planning and scheduling involves all activities carried out on the job shop floor to ensure a zero downtime of operation. Scheduling activities vary from one industry to the other but the main activities are mainly to ensure continuous improvement of operations of equipment, plant and machinery.

Over the past few years, we have visited the most of Kosovo enterprises, and the most of their industrial work activities and scheduling operations are done without application of any software for planning or scheduling but they preferred to do their job via manual paperwork. Therefore, we have chosen one metalworking company to record their process of operations and their manual paperwork. Computer Aided Design for the planning and scheduling have been used in order to improve their work activities, minimize the time of activities and to optimize processes. Commercial software package is used to demonstrate how planning and scheduling techniques will help enterprises to optimize their processes.

3.1 Usage of program package “LEKIN®”

Genetic Algorithm-GA for process planning and scheduling is used to obtain the result of the objectives where selection of the best process plan and scheduling of jobs in a job shop environment are done simultaneously.

From literature review we have noticed that a lot of algorithms are created for solving problems in process of scheduling and there exist several program packages for solving scheduling problems. For solving our problems, we have used the program package “LEKIN®” developed at the Stern School of Business, NYU. Major parts of the system were designed and coded by Columbia University students. The package of this program particularly developed for the exact and heuristic solution, genetic algorithms are created and implemented for solving open shop scheduling problems. Algorithm generates a randomly initial population, but we also can make a good starting solutions by selecting appropriate constructive heuristics for its generation.

Genetic Algorithm – GA is developed by John Holland in 1960. GA is an evolutionary computation algorithm that has objective to model adaptation capability of a system, for example in production scheduling system [9].

3.2. Problem definition

This step determines the problem on the job shop scheduling in manufacturing industry, are chosen to investigate scheduling processes in a company of metalworking industry, jobs should be proceeding to machines for processing, where jobs represent activities and machines represent resources and each machine can only process one job at the time. We will focus on the low makespan value system also known as job-shop scheduling, are used the real case data gained from manufacturing company. The following notations throughout the case are used:

- Number of jobs which will be processed are indexed with *j= job (j=1,2,….,n),*
- Number of machines are indexed with *i= machine (i=1,2,…..,m),*
- The transfer time will not be taken in account,
- P – is processing time,
- W – is waiting time,
- Ci – is completion time of job i.
- Fi=Ci-ri - is flow time of job i, when *ri* is release date
- Li=Ci-di – is lateness of job i, di is due date
- Ti = max {0;Li}, Li>0 – is tardiness of job i,
- Ei=max{0,-Li} – is earliness of job i,
- Ni – is number of tardy jobs.

Now, JSSP – the job-shop scheduling problem is described as below:

1) Sets of *Job J = {J1,J2,…..,Jj} | j = 1,2,3,……,n 2,*
2) Machine sets *M = {M1,M2,……,Mi}| i = 1,2,3,……,m,*
3) Processing time for each Job *Pij = {P11,P12,………,Pij},| i = 1,2,3,……,n ; j = 1,2,3,……,m*
4) Transfer time, but in this case transfer time will not me in consideration.

Also, jobs should be processed through the machines in a particular order or also known as technological constraint. The makespan is a maximal time that required for all operations to complete their processes, while mean flow time is the average time required for all operations. Our main reason is to minimize makespan value (C max = max {C j}) and making some solutions under constrains.

In our problem the mathematical description includes the following elements:

- Set of machines M: M={M1,M2,M3,M4}.
- Set of Jobs J: J={J1,J2,J3,J4,J5}.

By selecting a suitable process plan and also machining resource, the minimize of makespan is the aim of process planning and scheduling or any other objective function for each job along with a complete schedule that satisfies all precedence constraints.

Some assumptions used in this research are:

1) The jobs and machines are independent.
2) The priorities of jobs are given with weight (wj) and each job has their value of priority.
3) Each machine can process only one operation.
4) All machines are available at time zero
5) Each process needs to be processed during an uninterrupted period on given machine.
6) The release date (rj) for jobs is different, two jobs starting later than others.
7) The setup times are independent of the jobs sequence and are included in the processing times as it seems in table 1
8) The transfer time between machines will be not taken in account as it mentioned earlier.
9) There are no interruptions or machine breakdowns on the shop floor.

Table 1. Data gained from manufacturing company

Jobs	**Release date r_j**	**Processing time P_{ij}**				**Due Date d_j**	**Weight w_j**
		M1	M2	M3	M4		
J1	2	10	13	8	6	68	13
J2	0	12	9	4	5	65	10
J3	0	7	11	6	8	69	15
J4	5	13	15	6	11	71	9
J5	0	11	12	7	9	70	11

3.3 Proposed method

For solving problem, we have used a package software "LEKIN", in generic job shop scheduling system, it includes a number of scheduling & heuristics algorithms. The software allows the user to link and test his own heuristics and compare their performance with the heuristics algorithms that are embedded in the system. Our problem will be solved in machine environment – Job Shop, the reason is to generate such a schedule in the process of job shop scheduling using LEKIN® scheduling software using various dispatching rules and heuristics algorithms and to explore the chances to minimize the Makespan and by using objective function for minimize The Total Flow Time, The Total Tardiness, The Total Weighted Flow Time, and The Total Weighted Tardiness.

3.3.1 Methods: Dispatching Rules

The 5 jobs should be processed in 4 machines; those have different operations. According to their processing time due dates these jobs scheduled to minimize makespan. There are following rules selected from many existing priority scheduling rules to obtain optimum sequence.

3.3.2 Methods: Built-in Heuristics

In the LEKIN package software also are methods that are built-in-heuristics in minimizing flow times of job shop scheduling. These are:

- Shifting bottleneck heuristics
- Local search heuristic
- Hybrid methods

Here in this solving problem in Job Shop Scheduling, also shifting bottleneck heuristic has been considered with its four options:

- The rule - General SB Routine (most objectives)
- Objective Specific routines: SB/sumwT (Total Weighted Tardiness)
- Local Search sum(C) and
- Objective Specific routines: SB/Tmax (Maximum Tardiness, Makespan)

4. Results and discussion

In scheduling problems, there are many simple dispatching rules (priority rule) for scheduling. To obtain a good schedule for number of different objective in different cases are developed priority rules. These rules are designed for sequencing many jobs without many effort and with less time. Based on the graphics which we have obtained from software First Come First Serve (FCFS) and Shifting Bottleneck / sum(wT) (DASH) rules are chosen as the benchmark rules. Figure 2 shows process of Algorithm running, in case that Objective Function is Makespan. In same way we can have choose another Objective Function for optimization such as: Total Tardiness, Total Weighted Flow Time, etc.

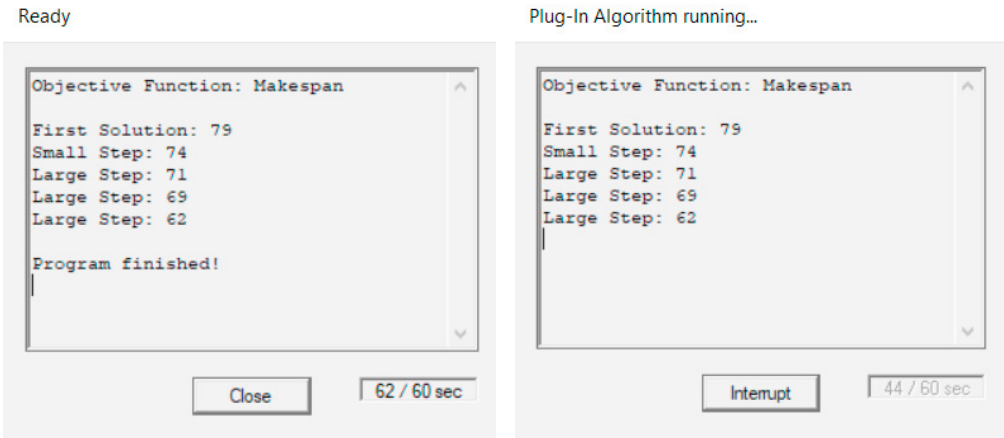

Fig.2. Algorithm running in case of minimization Makespan

After the Algorithm is ready we have won results and they will be presented graphically for each case of different Objective Functions. Figure 3 shows that Makespan is low when DASH rules and General SB Routine are followed, Max Tardiness is low when DASH and FCFS rules are followed (fig.4), Total flow time will be low when FCFS and DASH rules are followed (fig.5), Number of late job will be low for FCFS and Shifting Bottleneck rules are followed (fig.6). Whereas from fig. 3 we have noticed that makespan is higher when: Apparent Tardiness Cost Setup (ATCS), Critical Ratio (CR), Earliest Due Date (EDD), Local search, Longest Processing Time first (LPT), Minimum Slack (MS), Shortest Processing Time firs (SPT) and Weighted Shortest Processing Time first (WSPT) rules are followed.

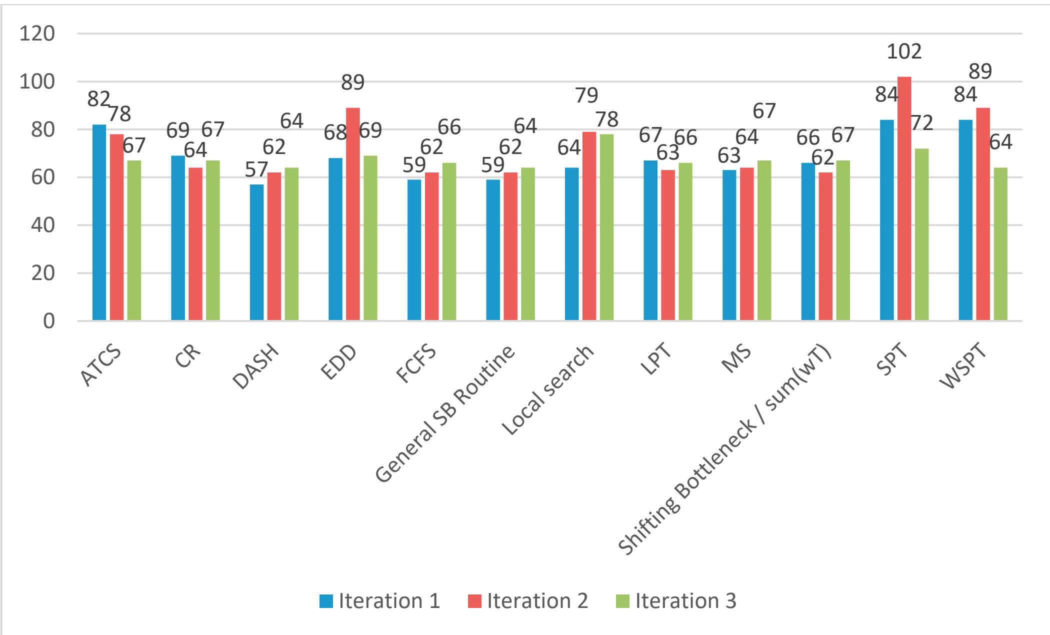

Fig. 3. Makespan Cmax for various solutions

Maximal Tardiness (Tmax) for various solutions is when ACTS, SPT and WSPT rules are performed (fig.3).

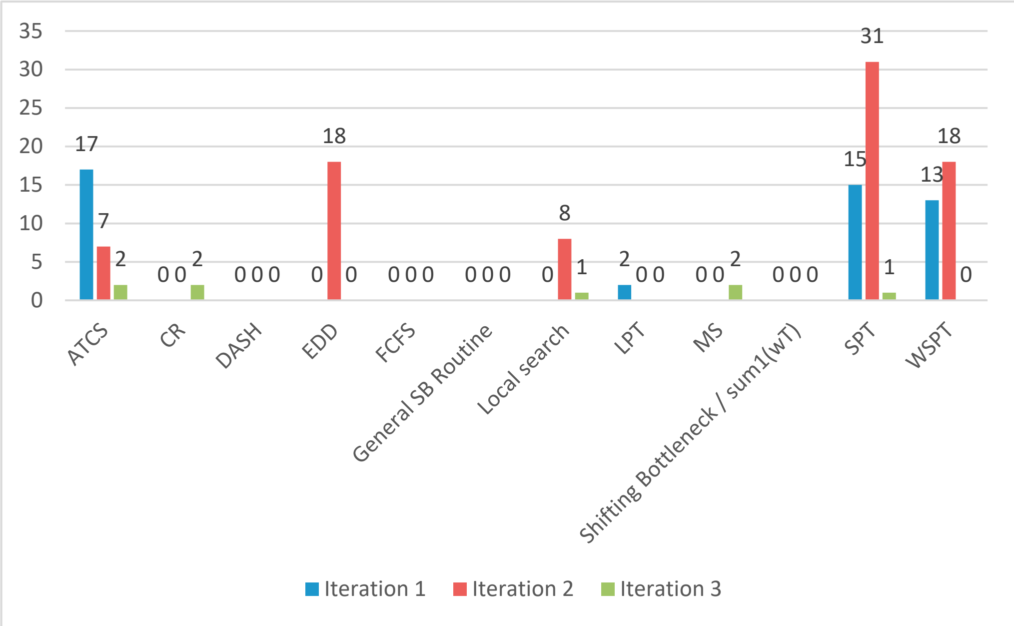

Fig. 4. Maximal Tardiness (Tmax) for various solutions

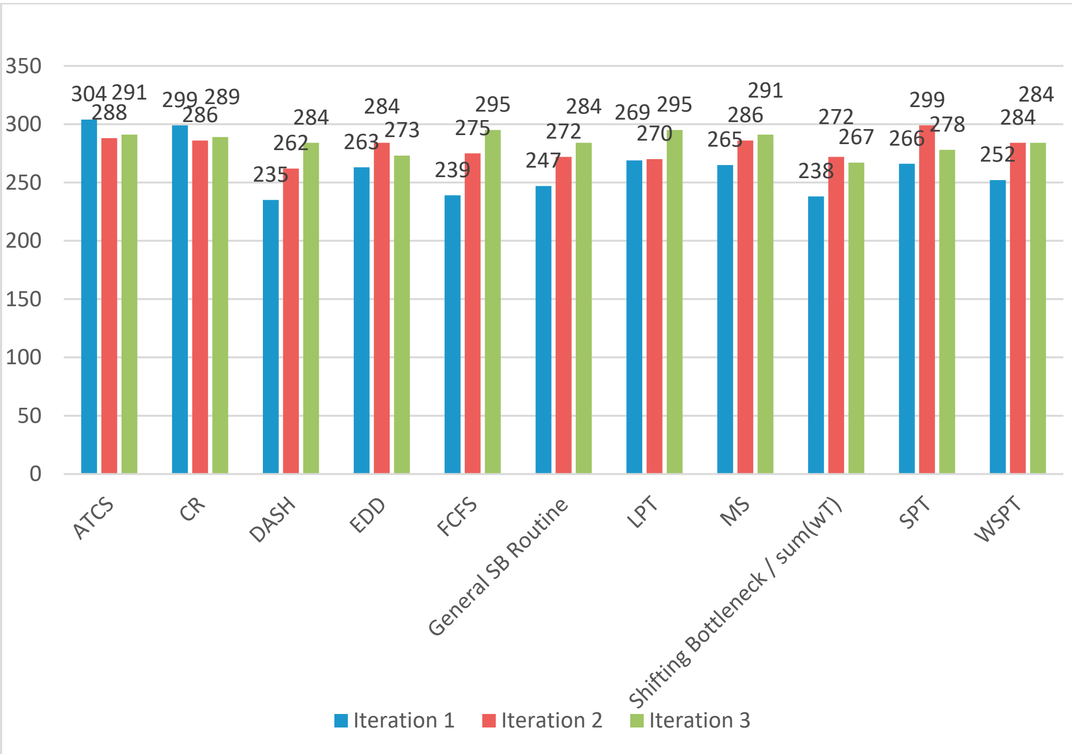

Fig. 5. The Total Flow Time Cj for various solutions

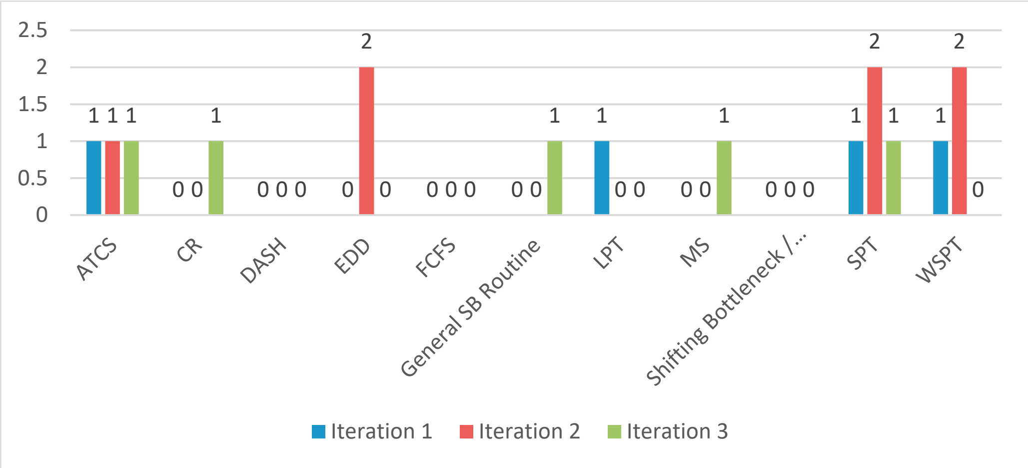

Fig. 6. The Total Number of Late Jobs ∑Uj

This instance is based on real case study problem in metalworking manufacturing company. We have recorded process of manufacturing in the company in case with 5 jobs and 4 machines. Problem has been solved and the company has been adopted in their process of scheduling.

5. Conclusion

In this article, we proposed some solutions for solving the job shop scheduling problem, which asks for an arrangement of a sequence of jobs in certain machines. The proposed solution is investigated on a real case problem, GA and package of LEKIN software has been used in which found to successful obtain the good solution value for the instances in every run, dispatching and heuristics rules are used to obtain results. We have focused on job shop scheduling problem using Bottleneck Heuristic Algorithm to minimize the makespan time, the objective Function is used also to minimize The Total Flow Time, The Total Tardiness and The Total Weighted Flow Time. Based on results, we can conclude that the application of computer to solve problems of scheduling in a shop floor increase productivity, shorten time of production, and indicate in the lean manufacturing.

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