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Cellular manufacturing system and its application in a furniture factory

Stanični proizvodni sustav i njegova primjena u industriji namještaja

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ABSTRACT • *Recently, market demands have been showing a clear tendency towards producing goods in smaller lots and with increased variety. This is why many companies, which manufacture a variety of products in large lots, suffer from many problems in designing, planning and production stages of products manufacturing. Cellular Manufacturing System and Group Technology are two accepted solutions to the problem of productivity in batch-production systems. Based on the sameness or similarity of operations, parts are classified into part families and machines are also grouped into machine cells. Cellular Manufacturing System and Group Technology emphasise that many problems are essentially similar, and hence collecting similar problems in a group and finding just one solution for them result in time and labour saving.The aim of this study is to simplify the part flow, to save the area and to shorten the transportation distances with the use of Cellular Manufacturing System. In order to group the parts into part families by their design and operational features, King's Rank Order Clustering Algorithm was used as the classification method. For this purpose, a computer program with five stages was developed in the Basic Language. This manufacturing system was established in a furniture factory by setting up four different cells. The machines within the cells were rearranged into a U-shaped layout. The results demonstrate that the part flow was simplified, the transportation distances between machines were shortened by about 44.3 % and the area needed for the production was reduced by 36 %.*

Key words: *Cellular Manufacturing System; Group Technology; Cellular Layout, Furniture Industry.*

SAŽETAK • *U tržišnim se zahtjevima u posljednje vrijeme očituje jasno nastojanje za proizvodnjom manjih količina dobara te za povećanom varijabilnosti/različitosti. To je razlog zbog kojega tvrtke što proizvode velike količine različitih proizvoda imaju problema u dizajniranju, planiranju i fazama proizvodnje. Celularni (stanični) proizvodni sustav i grupna tehnologija dva su prihvaćena rješenja problema produktivnosti u sustavu proizvodnje. Na temelju identičnosti ili sličnosti operacija dijelovi proizvoda podijeljeni su*

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u familije obradaka, a strojevi su grupirani u skupine. Stanični proizvodni sustav i grupna tehnologija naglašavaju da su mnogi problemi u biti slični, i zbog toga okupljanje sličnih problema u grupe i pronalaženje samo jednoga rješenja za njih rezultira uštedom vremena i rada. Cilj je ove studije pojednostaviti protok obradaka kako bi se uštedilo na radnoj površini i skratile transportne udaljenosti uporabom staničnoga proizvodnog sustava. Kako bi se obradci grupirali u familije obradaka prema njihovim obilježjima vezanima za dizajn i načine obrade, korišten je Kingov algoritam za rangiranje i grupiranje. Za tu je svrhu u programskom jeziku Basic razvijen računalni program s pet stupnjeva. Taj proizvodni sustav uveden je u industriji namještaja uspostavom četiri različite stanice/grupe. Strojevi unutar stanica postavljeni su u obliku slova U. Rezultati pokazuju da je protok obradaka pojednostavnjen, smanjene su transportne udaljenosti među strojevima za oko 44.3 % i potrebna proizvodna površina za 36 %.

Ključne riječi: *stanični proizvodni sustav, grupna tehnologija, raspored stanica, industrija namještaja*

1 INTRODUCTION
1 UVOD

Manufacturing of chemical products, where the raw material is a liquid or gas which undergo a series of transformations, is an ideal example of the continuous material flow in a transformation process. Here, the speed of production is high and the flow speed is regular (Barutcugil, 1988; Durmusoglu, 1986; Durmusoglu, 1989a; Tanyas, 1995).

In order to make fluent the discontinuous material flow, it is necessary to use smaller lots, even to reduce them to single units. This is accomplished by use of Cellular Manufacturing System (CMS) and Group Technology (GT).

1.1 Cellular Manufacturing System and Group Technology
1.1 Stanični proizvodni sustav i grupna tehnologija

CMS is designed to process part families of similar manufacturing characteristics by groups of operations, groups of workers, and especially by machine groups. All facilities and units in a cell are organized so as to manufacture the parts which enter into a cell. This kind of approach is aimed at achieving a small system's effectiveness.

Some authors consider Cellular Manufacturing (CM) as an independent system and Group Technology (GT) as a means for its designing. The basic advantage of GT is the simplicity of the work flow compared to process-oriented layout and its ability to provide product-oriented layout without any significant loss of balance between the operation time and productivity. Another important result of CM is that it requires flow control instead of stock control (Devries et al. 1976).

Machine groups operating as part families established with the use of GT, are called *"cells"*. The parts manufactured in more than one cell are *"exceptional parts"*, which make the work flow more complex. For this reason exceptional parts are manufactured by:

- suppliers,
- by use of machines designed for the movement of parts between the cells by cells as shared facilities,
- installation within both cells,
- modification of the method after carrying out work analysis.

U-shaped layout permits the workers of the cells to go from one machine to another or from one work to another when necessary. The distance between cells must be short, machines and equipment must be flexible and their use as simple as possible. The machine operators must be able to control and repair them. The machines must also be loaded according to critical machine capacity (Kone, 1989).

The aim of this study is to simplify the part flow, to save the area and to shorten the transportation distances with the help of Cellular Manufacturing System.

2 MATERIALS AND METHOD
2 MATERIJALI I METODA

2.1 Materials
2.1 Materijali

The study was carried out at a factory which produces modular furniture of nine different types (wardrobes, tables, bunk beds, book shelves, etc.). The units produced for middle and high income costumers are the standard furniture. The manufacturing area of the factory was 1435 m^2 and the number of workers was 106. The machines used in this factory are listed in Table 1.

Code - *Oznaka*	**Machine** - *Stroj*
M1	Panel sizing machine – *stroj za krojenje ploča*
M2	Double end tenoner – *obostrana čeparica*
M3	NC panel sizing machine – *NC stroj za krojenje ploča*
M4	Circular saw with sliding table – *kružna pila s kliznom pločom*
M5	Edge bander – *stroj za obrubljivanje*
M6	Edge bander – *stroj za obrubljivanje*
M7	Multi boring machine – *viševretena bušilica*
M8	Hand tool drilling – *ručna bušilica*
M9	Sub-assembly – *podsklopovi*
M10	Circular saw – *kružna pila*
M11	Wide belt sanding machine – *širokotračni stroj za brušenje*
M12	Assembling drawer frame – *spajanje okvira ladice*
M13	Fixing drawer bottom-pad – *učvršćivanje podnice ladice*
M14	Spindle moulder – *glodalica*
M15	Spindle moulder – *glodalica*
M16	Assembling of desk table – *spajanje ploče stola*
M17	Fixing drawer slipways – *učvršćivanje vodilice ladice*
M18	Smoothing drawer slipways – *glađenje vodilice ladice*
M19	Assembling of nightstand – *spajanje noćnog ormarića*
M20	Argraf – *shema spajanja*
M21	Assembling of bed – *spajanje kreveta*
M22	Cleaning – *čišćenje*
M23	Touching up – *popravljanje*
M24	Mounting of hardware – *grupiranje elemenata*
M25	Packaging – *pakiranje*

Table 1
Factory machines
Tablica 1.
Strojevi u tvornici

Figure 1 shows the product-oriented layout of the machines (M1, M2, M3, M5, M6, M7) and process-oriented layout of the machines (M9, M14, M16, M19, M21, M22, M23, M24, M25). As a result, the work flow is simple in the product-oriented layout, and complex in the process-oriented layout. Since the set up times of M5, M6 and M7 are longer, parts processed are accumulated in front of these machines. For this reason M1, M2, M3, M5, M6 and M7 were kept further away than the process-oriented layout machines (Tanritanir, 1993).

Preference was given to CMS in this factory as this proved to be the way to solve problems caused by lack of place and to simplify the work flow, which was very complex.

2.2 Method
2.2 Metoda

King's Rank Order Clustering Algorithm was applied to determine the number and composition of the cells, (Black, 1988; King, 1988; Durmusoglu, 1989b; Durmusoglu, 1991; Durmusoglu and Nomak, 2000). For this purpose, a computer program with five stages was developed in the Basic Language. These stages are as follows:

1. Entering data
2. Program running
3. Determining machine cells
4. Determining part families
5. Determining performance of cellular system.

2.2.1 Coding of machines
2.2.1 Kodiranje strojeva

In order to apply the King's Rank Order Clustering Algorithm by use of computer, machines and parts must be coded. Coding was done in accordance with the work flow. Work-benches were also considered as machines.

2.2.2 Coding of parts
2.2.2 Kodiranje dijelova proizvoda

Before coding, similar parts were grouped together. The same code number was given to the parts of the same size, which undergo similar operations in the same module. After giving code numbers to 25 machines (M) and to 126 parts (P), the work flow diagrams were developed as the basis for the first part-machine matrix according to the grouping algorithm of King's Rank Order Clustering (Table 2).

3 RESULTS AND DISCUSSION
3 REZULTATI I RASPRAVA

3.1 Determining of cells
3.1 Određivanje stanica

To apply CMS, different cells are to be determined by use of GT. For this purpose, Part-Machine Matrix was designed according to King's Algorithm (King, 1988). Processing of all parts on work-benches (M22, M23, M24 and M25) has adverse effect on grouping. By the same

Table 2
The first part-machine matrix
Tablica 2.
Prva matrica dio proizvoda - stroj

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25
P1	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P2	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P3	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P4	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P5	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P6	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P7	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P8	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
P9	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P10	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P11	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1
P12	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1
P13	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P14	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1
P15	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P16	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P17	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P18	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P19	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P21	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P22	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P23	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P24	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P26	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P29	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	1
P30	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P31	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	1
P32	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	1
P33	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	1
P34	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	1
P35	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	1
P36	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P37	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P38	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P39	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
P40	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
P41	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
P42	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
P43	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1
P44	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P45	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P46	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P47	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P48	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P49	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P50	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1
P51	1	1	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
P52	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P53	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P54	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P55	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P56	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P57	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1
P58	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
P59	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
P60	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
P61	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
P62	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1
P63	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	1	1	1	1
P64	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	1	1	1	1
P65	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	1	1	1	1
P66	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	1	1	1	1
P67	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	1	0	1	1	1	1
P68	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	0	1	0	1	1	1	1
P69	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	0	1	0	1	1	1	1
P70	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	0	1	0	1	1	1	1
P71	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	0	1	0	1	1	1	1
P72	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	0	0	1	0	1	0	1	1	1	1
P73	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
P74	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
P75	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
P76	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
P77	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
P78	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
P79	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P80	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P81	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P82	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P83	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P84	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P85	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P86	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P87	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P88	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P89	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P90	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P91	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P92	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P93	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1
P94	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1
P95	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	1	1	1
P96	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1
P97	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P98	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P99	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P100	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P101	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P102	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P103	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
P104	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
P105	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1
P106	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
P107	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P108	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P109	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P110	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P111	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P112	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P113	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P114	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1
P115	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
P116	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
P117	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
P118	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
P119	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
P120	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1
P121	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1
P122	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	1
P123	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1
P124	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
P125	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Table 3
The last part-machine matrix (6th operation).
Tablica 3.
Zadnja matrica dio proizvoda - stroj (šesta operacija)

	M2	M5	M1	M9	M14	M19	M21	M16	M3	M4	M6	M10	M13	M11	M12	M15	M18
P1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P3	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P4	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P5	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P6	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P7	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P9	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P43	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P44	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P45	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P46	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P47	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P48	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P49	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P51	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
P17	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P18	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P39	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P40	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P41	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P42	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
P94	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
P10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P11	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P12	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P13	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P14	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P15	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P16	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P19	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P56	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P57	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P78	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P79	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P80	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P81	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P83	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P84	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P85	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P86	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P87	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P88	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P89	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P90	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P93	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P97	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P98	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P99	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P100	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P101	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P102	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P103	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P104	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P106	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P8	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P50	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P82	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P91	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
P95	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
P92	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
P52	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P53	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P54	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P55	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P115	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
P116	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
P117	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
P118	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
P119	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
P120	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
P125	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
P126	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
P29	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0
P31	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0
P33	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0
P34	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0
P35	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0
P30	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P32	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P36	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P37	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P38	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P105	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
P121	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P122	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P123	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0
P107	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P108	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P109	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P110	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P11	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P112	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P113	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P114	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0
P124	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
P96	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
P58	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
P59	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
P60	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
P61	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
P62	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
P63	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1
P64	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1
P67	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1
P68	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1
P69	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1
P72	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1
P73	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0
P74	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0
P20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
P21	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
P22	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
P23	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
P24	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

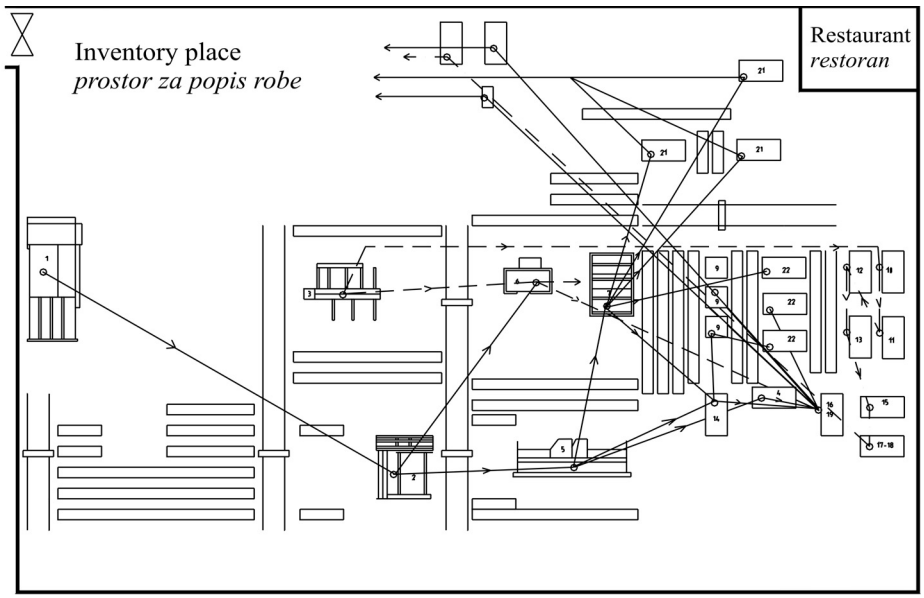

Figure 1
The layout of the factory
Slika 1.
Raspored strojeva u proizvodnom pogonu

token, these machines were taken out of the matrix and used within the last cell.

Grouping was not successful with the use of King's Algorithm: in M7 several parts were processed, M8 was required by all cells, M17 and M20 had an adverse effect on grouping. Also, these machines were taken out of the matrix. When part-machine matrix was examined, which was obtained as a result of the 6th iteration, three diagonally piled cells were obtained. White boxes outside the cells are the exceptional parts to be manufactured in more than one cell (Table 3).

In terms of operation, the first and second cell are *Dimension Cells*, the third cell is the *Drawer Cell* and the fourth cell is the *Cleaning and Packaging Cell*. The reason for forming two dimension cells is that M2 is unable to operate with parts smaller than 25 cm and such parts have to be processed in another cell which contains M3. Also the long parts are assembled on M9 in the first cell; the small parts are assembled on M16, M19 and M21, which are in the second cell (Tanritanir 1993).

3.2 Improvements of application of Cellular Manufacturing System
3.2 Poboljšanja primjene staničnoga proizvodnog sustava

It can be seen in Table 3 that some parts are exceptional, which has an adverse effect on the cell criteria. To eliminate exceptional parts it is necessary to carry out the following changes:

1. The changes on the work flow of parts: Considering the backward movements, which are not seen in the first part-machine matrix, the parts that undergo similar operations in every cell were grouped. Subsequently, sub-solutions were suggested for sub-groups in order to manufacture them in the same cell.
2. The changes on the assignment of machi-

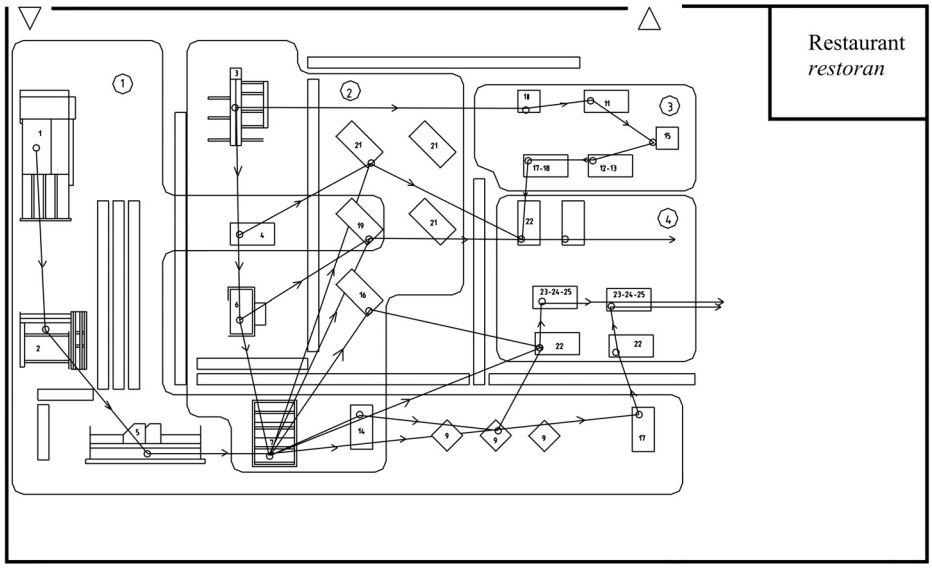

Figure 2
The layout of the factory in the cellular manufacturing system
Slika 2.
Raspored strojeva u staničnom proizvodnom sustavu

First Machine *prvi stroj*	Last Machine *zadnji stroj*	Distance, m – *udaljenost, m*	
		Traditional *tradicionalno*	Cellular *stanično*
M1	M2	20	1,9
M1	M20-M22-M23	27	27
M2	M5	8	2,4
M3	M4	28	1,9
M3	M6	7	5,8
M3	M10	42	13
M3	M20-M22-M23	14	22
M4	M6	23	1,9
M4	M9	3	14
M5	M7	4	2,5
M5	M9	10	18
M5	M20	14	19
M6	M7	5	5
M6	M18	31	23
M7	M9	8	10,5
M7	M14	11	2
M7	M19	23	10
M7	M21	17	13
M7	M22	15	15
M9	M14	4	7
M10	M11	2	1,9
M11	M15	1	1,1
M12-M13	M17-M18	4	1,9
M15	M12-M13	2	1,1
M16	M22	18	9
M17	M22	16	3
M17-M18	M22	20	2,4
M19	M22	18	1,8
M21	M23-M24-M25	22	8
M22	M23-M24-M25	25	1

Table 4
Distances between machines
Tablica 4.
Udaljenosti između strojeva

nes to cells: According to the King's Algorithm, the assignment of machines to cells is as shown below:

1. Cell: M1 - M2 - M5 - M9 - M14
2. Cell: M3 - M4 - M6 - M16 - M19 -M 21
3. Cell: M10 - M11 - M12 - M13 - M15 - M18
4. Cell: M22 - M23 - M24 - M25

In order to provide a balanced part flow, M3 was used as a facility shared by the second and third cell. M4, M7 and M14 were used as shared facilities by the first and second cell. The cheaply obtained machines M8, M17 and M20, were provided whenever necessary to the first, second and third cell. The assignment of machines to the cells after implementing changes was as follows:

1. Cell: M1 - M2 - M4 - M5 - M7 - M8 - M9 - M14 - M17 - M19 - M20
2. Cell: M3 - M4 - M6 - M7 - M8 - M14 - M16 - M17 - M19 - M20 - M21
3. Cell: M3 - M10 - M11 - M12 - M13 - M15 - M17 - M18 - M20
4. Cell: M22 - M23 - M24 - M25

3.3 Rearrangement of the factory layout
3.3 Preuređenje rasporeda strojeva

All parts operated in the first, second and third cell move to the fourth cell which contains M22, M23, M24 and M25. In order to achieve this, the fourth cell has to be positioned between the cells. The workbenches in the fourth cell are placed near the border of the first cell which sends more parts to the fourth cell. The drawer cell was close to the other cells and its machines were rearranged according to work flow, so that the transportation time of the parts sent

to this cell from M3 was shortened. U-shaped flow was the basis for the rearrangement in machine layout in the cell. Stock places of cells were determined according to the level of the average demand (Figure 2).

4 CONCLUSION
4 ZAKLJUČAK

As a result, the movement of parts was facilitated in this furniture factory and hence unnecessary movements were minimized. Thus, the shared use of some machines between cells became possible. With the help of the Cellular Manufacturing System in this furniture factory the movement of parts was simplified and the area saved by 36 % (from 1435.2 m^2 down to 912 m^2). In addition, the transportation distances between machines were also shortened by 44.3 % (from 442 m down to 246.1 m) as shown Table 4.

5 REFERENCES
5 LITERATURA

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