PLANT LAYOUT AND DESIGN THROUGH THE SIMULATION AND INCREASING THE CAPACITY OF METAL WORKSHOP OF A FURNITURE FACTORY

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Abstract

The objective of this study, to be able to increase the capacity by meeting increasing demand and product variety in Boytas-2 Plant of Istikbal-Boytaş Furniture Industry and Trade Company that is furniture Leader of Turkey, is to build a plant layout that provides productivity, flexibility and high competition.

In this study, by making an efficient plant layout through the simulation of metal workshop, It have been provided capacity increasing and % 25 performance improvement based on material handling cost per unit in the new layout. In addition, by Promodel 4.2 software, current and new designed plant layout was compared in terms of operational costs according to 20 products. As a result, we show that average cost saving is about % 59 in the new designed system, by doing simulation study, the bottleneck in the machines (process) was determined and necessary precautions were recommended to remove it.

Key Words: *Simulation, Facility Layout, CRAFT, Modeling, Furniture*

1. Introduction

Under the manufacturing concept, facility layout may be defined as "the process of obtaining the optimal disposition of the physical facilities for a manufacturing unit" (El-Rayah and Hollier, 1970). With the increasing commercial pressure for industry to operate economically this imposes the requirement for the manufacturing facility to be designed for optimal economy, which infers the need for careful planning. The best to the plant layout problem is important for two reasons. Firstly, the material handling cost can comprise between % 30 and % 70 of the total manufacturing costs, dependent on whether the facility is planned on a product or process basis or the other types. Secondly, plant layout is a long-term, costly proposition, and any modifications or rearrangement of an existing plant represents a large expense both in terms of relocation and lost processing time and can often not be accomplished easily (Sule, 1994). The importance of the subject of plant layout and material handling is further suggested by Tompkins and White, who claim that:"It had been estimated that between % 20 to %50 of the total operating expenses within manufacturing are attributed to the material handling. Effective facilities planning can reduce these costs by at least % 10 to % 30 and thus increase productivity" (Tompkins and White, 1984). Cost reduction is provided better process control, elimination of waste and plant consolidations. Engineers are often assigned one of two major tasks: Either redesign an existing facility to meet current market demands, or design a new plant from scratch (Kyle and Ludka, 2000). One of the most effective methods for increasing plant productivity and reducing costs is to reduce or eliminate all activities that are unnecessary or wasteful. A facilities design should accomplish this goal in terms of material handling, personnel, equipment utilization, reduced inventories, and increased quality. Some typical facilities design objectives are to;

1. Support the organization's vision through improved material handling, material control, and good housekeeping
2. Effectively utilize people, equipment, space and energy.
3. Minimize capital investment.
4. Be adaptable and promote ease of maintenance.
5. Provide for employee safety and job satisfaction

Today, existing layout configurations will not meet the expectations and needs of the multi-product organizations (Askın et al., 1997) (Yang and Peters, 1998). It is a necessary that there is a need for a new generation of factory layouts that are more flexible, modular and more easily reconfigurable. Flexibility, modularity and reconfigurability could save factories the need to redesign their layouts each time their production requirements change. Relayout can be highly expensive and disruptive, especially when the entire factory has to be shut down and production stopped. The current choices of layouts, such as

product, process, fixed position layout and hybrid layouts do not adequately address the above needs because they tend to be designed for a specific product mix and production volume, both assumed to last for a sufficiently long period. In addition to these layouts, there are some next generation layouts such as distributed layouts, modular layouts, reconfigurable layouts and agile layouts. As a result, layout performance tends to deteriorate significantly with fluctuation in design parameters such as product volumes, mix, routings or product life-cycles (Türkbey and Zeydan, 1995).

2. Problem Definition

There are 3 furniture manufacturers listed in the ISO (Istanbul Chamber of Commerce) 500 in 2002. Turkey furniture industry (sector) have been expanding very rapidly. There are a lot of important producers and exporters in Turkey such as İstikbal-Bellona, Yataş, İpek, Kelebek, Tepe Group, and so on. We deal with plant layout and design through the simulation and increasing the capacity of metal workshop of Istikbal-Bellona group factory. Total Production area for metal workshop is approximately 2700 m^2. In the current plant, 23 different types of materials which comprises box, tube and eclips profile and other materials have been used. 1500 WIP products from these materials have been obtained and the materials have been come together with welding, resulting in about 300 finished goods. 1500 various types of materials pass from 98 different manufacturing process. In current facility area, there are 6 processing departments made up of (1). Profile storage area (2). Cutting (3). Bending (4). Drilling (5). Welding (6). Cleaning and Painting. Current plant layout is process (functional) layout. Most of today's fabrication facilities and those being designed for the near future use process layout configuration. A functional layout is notorious for its material handling inefficiency and scheduling complexity. Because of increasing demand, factory layout was not sufficient to meet coming demands. On account of this, they wished to buy new machines. Top management wished to know whether this decision is true or not and as a result, together with buying new machines, they wanted to make a new relayout. We made some capacity analysis in the factory. After determining the lack of capacity in the system (for some machines, there are some bottleneck for Capacity Utilization Ratio (CUR) and productivity), Top management made a decision to buy some machines. Current layout is given Figure 1. The main objective of this research project is efficiently (flexibility) improvement of layout to design a layout by using simulation consistent with organizational strategic objectives of company. The performance of the layout is measured in terms of the operating cost comparing the current operating cost and new operating cost through simulation. At the same time, the role of simulation as a tool for facility layout is exhibited in this study. This research project is carried out for a furniture factory producing 300 finished goods. Furniture manufacturing is an important component of Turkey manufacturing industry. However, the information used for conducting this project is real and not hypothethical. It is crucial to build a model of the system to use in the engineer's analysis to minimize errors in layout design, system behavioral assumptions, and capital costs. The furniture industry that is getting increased has begun to utilize ERP systems. Especially, they know before implementing the system must be evaluated the system performance in terms of layout design.

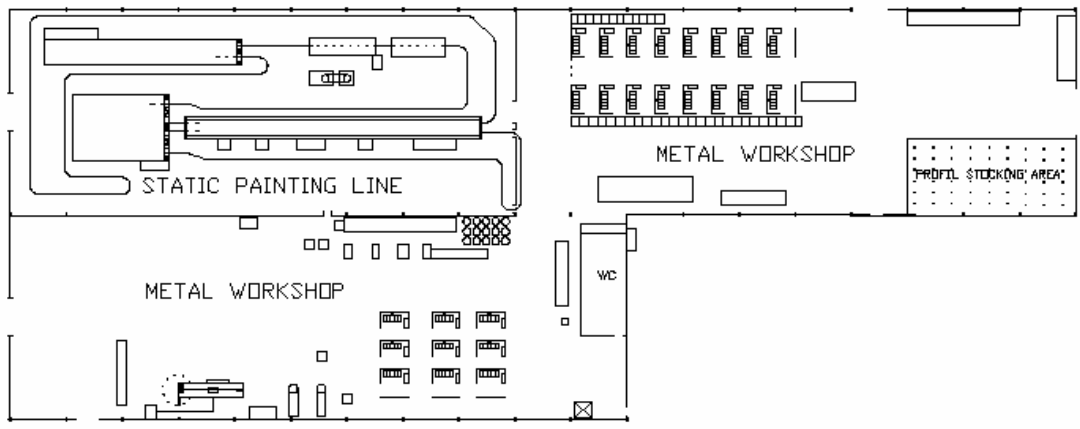

Figure 1. Current Plant Layout

3. The Working Methodology

Only an efficient and productive organization can survive in today's competitive market. As we know, after the satisfaction of internal customer (Worker, employees) in a business, external customer (cunsomer) may satisfy completely. On account of this factor, firstly, we made a questionairre whether the internal customer is satisfied or not in the business in terms of the working area; In order to prepare a new plant layout, firstly, below questions that was asked by ourselves and engineers in the firm had been answered, the answers of the below questions had been looked for;

Meanwhile, below questions was taken into consideration to be able to make a suitable layout.

1. Is there a suitable layout consistent with product layout?
2. Are there bottleneck machines? Are there any machines creating bottleneck?
3. Is any unused area (location) available?
4. Is material handling equipment enough? Much more? If it is much more, can we reduce it? Can we reduce the number of trucks by transferring with airline (conveyor) the material handling?
5. Can the material handling be reduced?
6. Can the workers work in the machines consistently? Is the machine working enough?
7. Can the machine capacity work consistent to product flow with maximum productivity?
8. Can the savings taken (obtained) by material handling convey to production?
9. Is the distance between machines consistent for working?
10. Can we get maximum production by using minimum workers?
11. Is there possible that we can locate the new machines consistent with manufacturing process together with increasing capacity?
12. If we dont't produce the Baza, can we use this empty area efficiently?If the demand reduces, can it be moved anywhere?

We have used a methodology to find these above questions

1. we made a questionairre as seen in Table 1 in the plant whether the workers, supervisors, shift engineers in the metal shop is consistent (satisfied) with working there or not.
2. In order to determine the process structure of manufacturing systems, we used process structure-manufacturing characteristics matrix as seen in Table 2 and Figure 2.
3. After determining the process structure and manufacturing characteristics, it is established product part/machine matrix as seen in Figure 3 by grouping products and according to product groups, manufacturing lines are established.
4. To find the operational costs in the shop was used the simulation. Afterwards, We made a comparison between the current real system operational cost, new designed system operational cost. Cost minimization is a performance measure for an efficient layout.
5. In order to minimize material handling cost for new designed layout, CRAFT was used.

4. Challenges Facing Operations Managers

The problems resulting from current plant layout are as follows;

1. Long material handling time is available between profile storage and the next step (cutting). That is, sequencing processes are not near one another.
2. As Product variability is medium and batch volume and some products volume, the requirement for buffer stock areas can not meet.
3. Because of the wrong use of some material handling equipments (Trucks without wheels), material handling cost is very high.
4. In order not to be used shelf systems that is suitable for profile stock areas, raw material Load/unload is very difficult.
5. To new machines that will come, Location site can not find for planning the production of chrome covered (plated) materials.
6. As the volume of the baza's that have been produced newly is very high, high buffer stock (areas) and assembly areas are needed/required.
7. Because of unwealthy condition in the working area, working performance of the employee is low.

Table 1. Questionairre Questions

Do you feel back pains resulting from working area?
Is the brightness in working area enough?
Is there any Loud noise in your working area? If yes, are you disturbed from this?
Is there any dust in your working area?If yes, are you disturbed from this?
Is your any fume (smoke) in your working area?If yes, are you disturbed from this?
Is your working area very cold in winter?
Is your working area very hot in summer?
According to you, ıs there any requirement for air conditioning in your working area?
Do you fear to make any job accident?
Is dining hall big enough?
Are you satisfied very well from foods?
Is there warning sign enough in your working area?
According to you, ıs the distance between machines enough?
Are the tools and equipments enough for your using?
Have you taken any education for the use of machines, equipments and tools?
Is there fire risk in your working area?
Is there anything that breaks up your attention in the working area?If yes, what are these?
Is working area, according to you, secure and safety? If no, why?
Have you any disease resulting from working area? If yes, what are these?
While working this firm (business), are you under stress? If yes, why?
Working in front of the machine, Do you think that will be made a job accident? What kind of accidents are there? Can you take any measurement?
What are your suggestions? What do you suggest related with your working areas?

Table 2. Current facility layout process characteristics and values

Process Characteristics	**Values**
Material Handling (forklift, truck, crane)	High
WIP (Work-In-Process)	High
Benefit from working place	High
Product variety	Medium
Scheduling and Coordination	Difficult
Cost ıdentification	Difficult
Flexibility	Medium
Productivity	Low
Investment Cost	High
Dull of Works	High
Process sensitivity versus breakdown	High
Production Volume (Lot Size)	Medium
Labor Satisfaction	Low
Provide the Quality	Medium
Uncertainty of Order Size	Medium
Uncertainty of oeration time	High
Acception the order on time	Medium

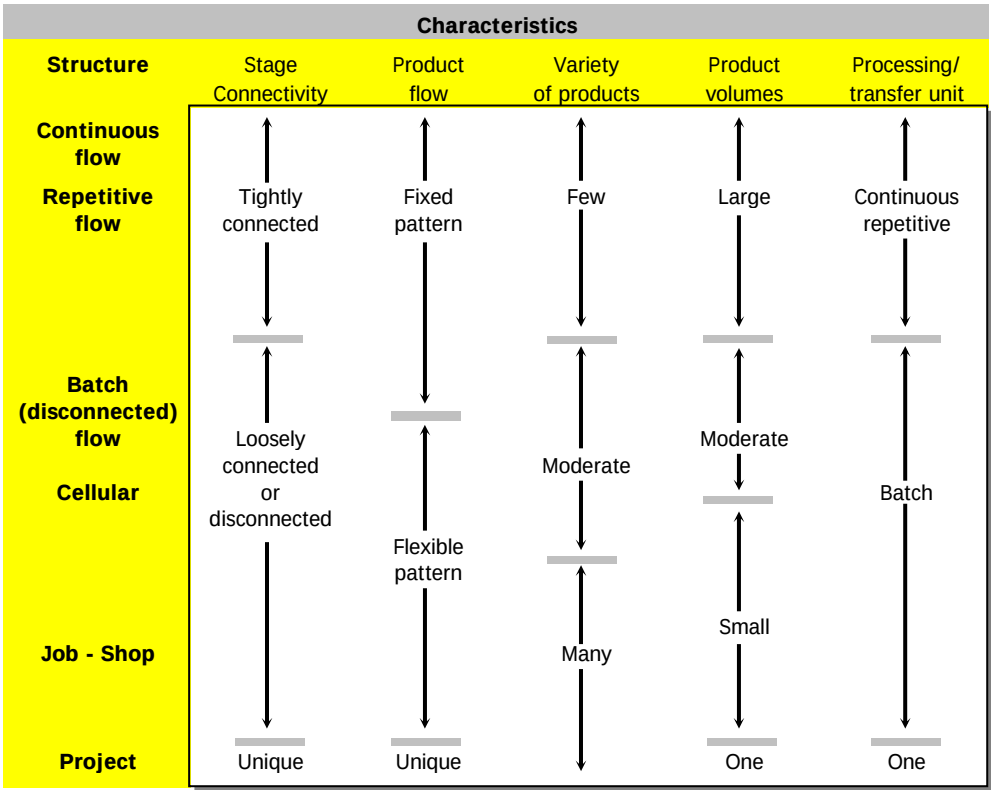

Figure 2. Process structure and production characteristics matrix

5. Product-Process Matrix

After determination of process structure of manufacturing system, the second important study is to constitute manufacturing flow lines. when examining the products that are produced in metal unit, it is generally separeted 5 groups. These are sofa, chair, subcontract, baza ve chrome coated products. For the most part, These products follow in flow through, according to flow system, cutting, bending, press-drilling, welding, polishing, phosphate-painting ve packaging. Thus, in this flow system, we used product-process matrix to form cellular blocks. In this matrix, flow routes of parts forming each one product have been grouped by using group technologies techniques and production lines have been formed in cellular. To minimise the number of machine duplications, a GT(group technology) algorithm was proposed. This GT algorithm is a combination of the clustering identification algorithm (CIA) and the Production flow analysis (PFA) (Letjman et al., 2002). Microsoft excel was used as a sorting tool. As an example, product-process matrix is given in Table 3. As a result, Metal Department is separeted into 5 section (cellular) :

1. Profile cutting, bending, press-drill department
2. Sofa, chair-sets, and subcontract welding department
3. Polishing (Cleaning) and welding department for Chrome plated (coated) products
4. Baza welding and assembly department
5. Phosphate and painting department

Table 3. Product-process matrix

Product Definition	Part Definition	Size	Long	Cutting	Sawing	Wending	Pressing	Automatic Bending	Pneumatic Bending	Manuel Bending
Destina Single	Metal Part Seat	25X25	1,175	1		3		2		
		25X25	0,445	1		2				
		25X25	0,240	1		3	2			
		93x2	Sheet Iron				1			
Destina Single	Metal Part Back	25x25	1,145	1		3		2		
		25x25	0,445	1		2				
		25X25	0,240	1		3	2			
		93x2	Sheet Iron				1			
Destina Single	Arm Metal Part	20X20	0,760			3	1			2
		20X20	0,140		1	4	2		3	
Destina Single	Metal Part Seat	25X25	1,875	1		3		2		
		25X25	1,145	1		2				
		25X25	0,240	1		3	2			
		20x20	0,505		1	2				
		93x2	Sheet Iron				1			
Destina Double	Metal Part Back	25X25	1,845	1		3		2		
		25X25	1,145	1		2				
		25X25	0,240	1		3	2			
		20x20	0,490		1	2				
		93x2	Sheet Iron				1			
Destina Single	Arm Metal Part	20X20	0,760			3	1			2
		20X20	0,140		1	4	2		3	
Destina Sofa	Metal Part Seat	25X25	2,515	1		3		2		
		25X25	1,785	1		2				
		25X25	0,240	1		3	2			
		20x20	0,505		1	2				
		93x2	Sheet Iron				1			
Destina Sofa	Metal Part Back	25X25	2,485	1		3		2		
		25X25	1,785	1		2				
		25X25	0,240	1		3	2			
		20x20	0,490		1	2				
		93x2	Sac				1			
Destina Sofa	Arm Metal Part	20X20	0,760			3	1			2
		20X20	0,140		1	4	2		3	

5.1. Comparison of Manufacturing Systems

In addition, If we examine defined manufacturing system for not only productivity but also flexibility, we can obtain that productivity is medium-high and flexibility is medium as seen in Figure 4.

5.2. Simulation Model and Products to be modeled

Simulation model, in the plant layout plan formed for some products, especially, for improving the productivity, to determine bottleneck resources from current resources and to find in operational costs is formed. Computer simulation was used as a validating tool for layout. Computer simulation has been constantly reported as a powerful and popular engineering and operations research tool to assist the organizations to achieve their goals (Law and Kelton, 2000). We built a simulation model according to products below. The parts that contribute approximately % 65 of the annual revenue of the plant are identified. Promodel 4.2 version was chosen to implement the simulation model due to its simplicity (Harrell et al., 2002). The simulation took under consideration the capacity of machineries and operational costs.

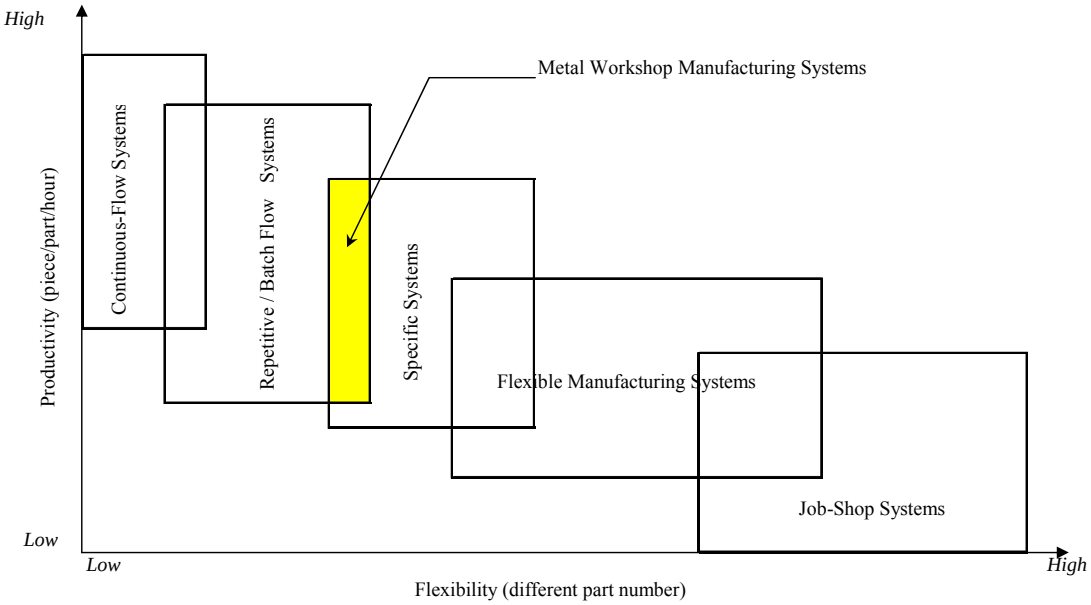

Figure 4. Comparison of manufacturing systems according to productivity and flexibility

Table 4. The products that was modeled

SOFA

Product Definition	**Part Definition**
Destina Single	Metal Part Seat
Destina Single	Metal Part Back
Destina Single	Arm Metal Part
Destina Double	Metal Part Seat
Destina Double	Metal Part Back
Destina Double	Arm Metal Part
Destina Sofa	Metal Part Seat
Destina Sofa	Metal Part Back
Destina Sofa	Arm Metal Part

ARM CHAIR

Product Definition	**Part Definition**
Mira Double Chests	Back Profil Chests
Mira Double Chests	Double Chests Back Profile
Mira Double Beds	Double Beds Leg Profile
Mira Double Beds	Double Beds Font Upper Profile
Mira Double Beds	Double Beds Back Profile
Mira Double Beds	Double Beds Wheeled Lower Frame
Mira Double Beds	Double Beds Seat Profile

SUBCONTRACT

Part Definition
Champion Bunk Travers Metal
Champion Bunk Ladder Metal
Champion Bunk Base
Champion Single Table Underside Metal
Champion Double Table Underside Metal
150x200 Baza

5.3. Model Evaluation

The most important results with simulation model are as follows;

1. In front of the welding process, large (serious) buffer stocks are established. As welding process have a long time. For elimination of this bottleneck and improvement of workshop responsiveness, by increasing the number of welding mould of products that are mostly produced, weldind process must be speed up.
2. % idle time in the machines of press, drill, pedrazzoli (Bending), imak is high. For using high productivity these machines, the number of products that will be produced in these machines must be increased.
3. Because of operational time differences, buffer stock (WIP) quantities is high.
4. To decrease the unit production costs must decrease the material handling time and increase the labor performance.

In addition, the simulation results of operational production cost of the new layout, and the simulation results of operational production costs of the current layout reasons of these differences are as follows;

1. Because of new coming machines, to increase the production capacity, production quantities per day decreased. Thus, this decreases the operational cost per unit .
2. As machines are grouped, material handling have been decreased, so, idle time reflects to production.
3. Production time tolerance is % 10.
4. The time is suitable with normal distribution.
5. Setup / changeover time added to operational time.

6. The Comparison of Old and New Plant Layout Plans

The comparison between Old plant layout and new plant Layout as seen in Figure 5 are as follows;

1. Working area for metal workshop is increased to %95 (except static paint, increased from 2650 m^2 to 5158 m^2)
2. In welding Process, the number of small welding cabin (3x3) was increased from 25 to 31. In addition, the number of 7 big (8x4) welding cabin was included to system. Why the welding cabins are increased are to increase the unit-time capacity of welding process that is a bottleneck process.
3. The spaces between welding cabins was widen and more satisfaction working area was provided.
4. Subcontract packaging that had been doing in the cover department before is included in metal workshop and the intensity that is in front of painting department was put away.
5. In the current Layout, sofa metals was put on the production line (band) after welding process and afterwards, it was put on the truck and cleaning hooks was hanged. But, in the new layout, sofa metals after welding process are being easily hanged to hooks by the side of workers without any material handling.
6. Bazas occupying a big place as a volume was removed the handling after welding and for welding, painting, assembly is allocated to a separate department. Baza in here, without any material handling, is sent to painting and assembly easily. In addition, for storage after assembly is allocated to enough space.
7. In the new layout, Gordion Baza can be produced easily.
8. In the new layout, stock area after cutting is broadened. So, it is to provide ready WIP to processes After cutting process, which is a bottleneck
9. In the old layout, these machines that is not sequencing is brought to successive and at the same time, As manufacturing system is flow type and cellular, productivity is increased.
10. The old Bewo cutting machine and new coming one side by side have been put, only one worker can control at the same time these two machines
11. In the old layout, chair smoothing process in the chair lathing is included in metal workshop.

12. We make larger room for buffer stock areas, therefore, WIP material handling is easier than the old one and plant layout have been arranged.

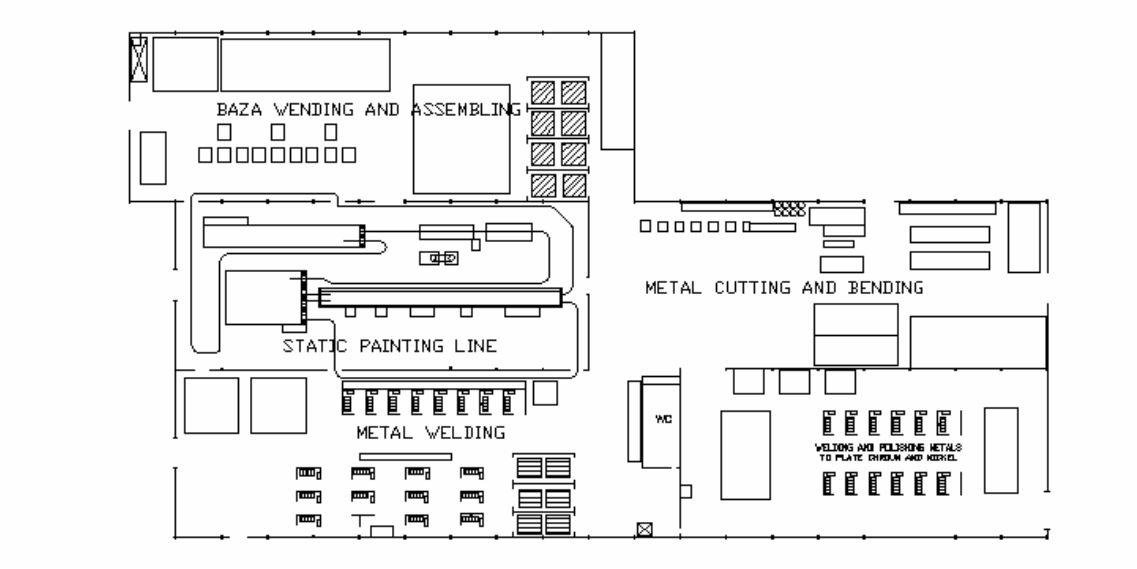

Figure 5. New designed layout

7. Simulation Results

After simulation model running, we got the results according to below Table 5. Afterwards, the last step is to analyze the plant layout for material handling cost saving. We got a CRAFT solution after analyzing the Layout. According to CRAFT Solutions, Because machines is near to each one and is close to each one, we see very little changes. With CRAFT Algorithm, in the new layout, material handling is improved %25. The differences are given in Table 6 with comparison.

Table 5. Operational costs comparison table based on current and old plant layout

Production Name	**Old Layout Cost (TL)**	**New Layout Cost (TL)**	**Savings**
Champion Bunk Travers Metal	3,573,107	1,447,959	%60
Champion Bunk Ladder Metal	8,679,904	2,692,461	%69
Champion Bunk Base	1,436,223	365,367	%74
Champion Single Table Underside Metal	1,224,350	143,656	%88
Champion Double Table Underside Metal	396,715	128,408	%67
150x200 Baza	3,641,102	2,168,194	%40
Mira Double Chests Seat Profile	716,230	326,724	%54
Mira Double Chests Back Profile	713,215	592,606	%17
Mira Double Beds Leg Profile	1,842,422	630,194	%65
Mira Double Beds Wheeled Underside Frame	1,890,032	956,735	%49
Mira Double Beds Font Upper	1,845,732	791,321	%57
Mira Double Beds Seat Profile	1,879,521	579,274	%69
Mira Double Beds Back Profile	1,526,501	675,143	%55
Destina Single Metal Part Arm	349,777	120,474	%65
Destina Metal Part Seat	421,467	236,376	%44
Destina Metal Part Back	413,702	235,563	%43
Destina Double Metal Part Seat	429,449	286,055	%33
Destina Double Metal Part Back	429,449	286,316	%33
Destina Kanepe Metal Part Seat	475,578	286,300	%39

Destina Kanepe Metal Part Back	475,578	286,214	%39
Grand Total	32,360,054	13,235,340	%59

Table 6. Differences table

New Plant Layout of Current Condition	New Plant Layout of ImprovedCondition
Drill	Pipe Bending
Press	İmak-2
Imak-2 and Circular Saw 1	Press and Profile Bending
Profile Bending	Drill and Manual Profile Bending
Manual Profile Bending	Circular Saw 2
Pedrazolli	Imak-1

8. Recommendations and Conclusions

Now, in order to increase the new Plant Layout productivity, we would like to propose for the system. These proposals are as follows;

The basics of ideal system approach from the productivity point of view

1. Quick Systems: Speed Changeover

In order to do speed production, Machines must be prepared as soon as possible. As Product variety is high, changeover time mustn't take long time. In Cutting, bending, press, and drill, some special methods must be improved to decrease the changeover and set up time. Internal setup time is to transform external set-up time. For instance, ınstead of preparing the mould after stopping the machine, we can prepare the mould while running. All Activities for Setup and changeover must be simplified. The methods that will provide to do all activities in the first time must be improved

2. Reliable Material Procurement

For a reliable material procurement, client and contracter strongly must collaborate each other. Thus, 5 factors of reliable delivery must take into consideration every time;

- Scheduling must be shared with contracters
- Product design must take part in contracters.
- Contracters must be helped to improve the production methods.
- Close contracters must be selected by place.
- Long time contractual and only one contracter must be used.

3. Decrease the Machine Breakdown: Total Productivity Maintenance

Poor maintenance of machines is very expensive and to put forward an unreliable production environment. Thus, to establish an reliable production environment must be taken into considerations below suggestions;

- Sufficient preventive maintenance must do without negligence.
- Speed machine must not operate and use.
- The losses resulting from dirty grease and chemical substances is to provide not to arise
- Machines must not prepare faulty.
- Operating and giving wrong the machine to material is to prevent.
- Make job design and train the operator.
- Establish overcapacity in machine.
- Clean up the machine everytime.
- Structural preperations and job supports to prevent the faulty in machine is to provide.
- Simple design for machines
- Collect true information relevant with machine.
- While wearing away a part of machine, if the other parst of this machine also wear away, change all together of all parts instead of one by one.

- Careful machine part procurement plan must be prepared. Main spare parts of the machines must have in stock.

4. Quality and Just in Time Production

There are 5 factors to produce a quality product:
- Product must design to product easily
- Products must take delivery faultless of Contractors
- Production process must not cause the fault
- If a faulty material part is produced, They must be determined quickly and the reason of problem must be eliminated.
- Trained Labor (at least high school)

The preceding process must deliver WIP on time for the subsequent process Otherwise, the subsequent process will be idle.

5. Continuous Improvement

All activities that is not added value in the company must be completely eliminated. This principle must be instutional and methods that will declare to workers everytime must be improved. The most successfull continuous improvement systems, production methods and to improve the products is to encourage the workers. Worker proposal systems, quality circles and autonomous working teams must be set up.

6. Labor Motivation

Some people want to do better his/her Works and make some contribution to the organization. Workers also want safety in the organization and some authorities. Thus, natural skills of workers must be come out. The worker must train and some authoties and responsibilities must be given. The workers must be given permission him/her to behave like decision maker. In the event of doing these, big creativity at workers and job loyalty will be priority (Martinish, 1997).

7. By placing (hanging over) scoreboard (lightened board) over the sequencing machines, we can provide transformation to JIT production system (pull system), so, we can make a link between machines. This scoreboard is made up of the number of production that are planned to be produced per day, the number of production that are produced per day, time, how many product must be produced that hour, a scoreboard we can prepare, so the productivity of workers or production system may be increased. Thus, the production may be related to demand.

8. During welding process in the current condition, The workers make welding with the other hand while holding the welding mask with one hand. Instead of this, by fixing the welding mask, so, the worker can make the welding more efficient with two hands.

9. An Industrial Engineering Department must be formed immediately, so each time and cost studies can be done. In addition to that, by using together with BAAN (ERP Software) and preactor (scheduling sofware), Production planning and tracking can be more efficient.

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