AL KUT JOURNAL OF ECONOMIC AND ADMINISTRATIVE SCIENCES
Publisher: College of Economics and Management - Wasit University

Mathematical Modeling and Optimization of Dynamic Resource Planning in Large-Scale Industrial Systems: A Quantitative Analysis Using Numerical Examples

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ABSTRACT:

The industry is facing enormous pressures due to energy, raw materials, labor, investment, and international competition. These trends have been going on for a long time and the problems are increasing day by day. Planning has become one of the strategic issues that determine the long-term operational profitability in the manufacturing industry. Integrated design refers to how different machines and equipment are arranged in a work environment to produce products (or provide services) to increase productivity and efficiency in multiple enterprises. Multi-path planning, detailed planning of parts, and calculation of the cost of moving parts based on the estimated machine load and the distance between machines are some of the differences between this model and others. In response to this problem, this research proposes a multi-objective mathematical programming model for the dynamic resource planning problem, which achieves the research objectives based on the instantaneous solution method and is validated using the problem solving speed model to reduce costs due to the objective. The movement of parts in the factory system, the cost of machine maintenance, as well as the cost of transporting, purchasing, and maintaining machines, thus increasing the overall efficiency of the system and creating balance in the system. The advantage of this model is that by integrating machines with each other, it tries to avoid excessive movement in the cell, thus increasing the efficiency of the cell. Some other variations of this model are multi-line design, node clustering, machine transport cost calculation, and package transport cost calculation, based on the distance between machines. The study solves a complex, multi-objective production planning model with up to 338,184 variables and 338,071 constraints, focusing on minimizing costs related to part movement, machine relocation, and operations. Using Maple, MATLAB, and GAMS software, the model dynamically adjusts machine and cell layouts over multiple time periods to optimize cost efficiency, considering machine purchase and maintenance. Key findings demonstrate the importance of strategic machine arrangement and cell configuration to reduce movement costs and improve system throughput, highlighting the model's ability to handle dynamic resource allocation. Recommendations include further research into multi-lane layouts, cost estimation refinements, and the application of this dynamic model to other complex production scenarios.

Keywords: industry- production- technology- maintenance- cost

1.Introduction

Production industry is the cornerstone of national development and represents the level of science and technology in any country. The production industry is the main pillar of national development and represents the level of science and technology of a country. With the intensification of competition in the market and the acceleration of substitution, the product of organizational production has changed towards production, personal, diverse, small hands and other production methods, which has led to the concepts of modes of production. Production becomes timely and intelligent, however, a traditional production line has a long production cycle, low work efficiency, low resource allocation, etc., and these problems can only be solved with intelligent optimization algorithms.

Therefore, production line optimization for intelligent manufacturing has gradually become a research topic in the manufacturing industry in recent years. With the improvement of living standards of mass production technology, the traditional can no longer meet the demand of the customer-oriented market; As a result, the manufacturing industry, in addition to adopting a design style that can quickly adapt to the needs of customers for a variety of products, must also study suitable production models to respond to fast delivery times. In the past decade, traditional features market was replaced by emerging factors such as changing market demand, the need for flexibility, shorter product life cycles, and mass customization, which drastically changed the production environment and forced industrial companies to adopt new types of Implement production paradigms. Re-configurable manufacturing systems (RMS) have grown as effective systems in dealing with current challenges that were rapidly changing their hardware, i.e. physical and software structures, and logical structures to address changes in market needs. Cell formation is the first step, In the design of production systems is cellular.

One of the strategic issues in the manufacturing industry is layout design, which determines the long-term efficiency of operations. Layout design means how facilities are placed in a working environment for producing products or providing services consisting of all kinds of machines and equipment for the productivity and efficiency of organizations as much as possible. The proper design of the workplace makes the flow of work in a line smooth, and accordingly, the amount of production and the quality of the organization's production increase.

On the other hand, at the level of performance management of processes and equipment, the estimation of maintenance and improvement of reliability is one of the most important concerns of engineers and managers of manufacturing industries. Various analytical methods have been developed to evaluate and manage reliability. The use of each of these analyzes depends on the stage of the life cycle, its priority equipment among other equipment, the amount of recorded data and other such factors. It should be noted that the types of reliability analyzes are related to each other and in solving problems caused by the decrease in the level of reliability can be used from different perspectives.

2. Literature review

Cell production, which is an innovative production strategy based on group production technology, is a method used to increase flexibility and efficiency in today's competitive production environments, such as flexible production systems and just-in-time production becoming [1].

One of the advantages of implementing cell production can be stated as follows [2]

Reduced setup time, reducing the inventory of parts under construction, reduce the cost of moving parts, increasing the efficiency of machines

A significant issue in cell production is the shortening of the production life cycle. Ignoring new products that are created can impose unforeseen changes to cell production systems in the future and cause production interruptions and unexpected costs. Therefore, changes in the production cycle should be considered in the design of the cells. Such models are called dynamic cell production systems (DCMS) [3].

In this model, we assume that the change in the composition and quantity of the demanded product can be predicted so that a multi-period planning is possible. has An example of a dynamic cell production problem over four periods is shown in Figure 1, which is based on a dynamic layout model is machines [4].'

If no cost is considered to change from one optimal configuration to another optimal configuration, the best strategy is to use the optimal configuration for each period. But the reconfiguration of cells imposes costs such as moving machines, installing and removing machines, lost production time, and re-starting due to reconfiguration costs.

A sub-optimal configuration is the best in a period because using this sub-optimal configuration may reduce reconfiguration costs and overall costs. "Therefore, when establishing production cells, it is crucial to account for the costs associated with cell reconfiguration, as these expenses significantly impact the overall economic efficiency of the production process"[6]. As mentioned above, the reconfiguration of cells is due to fluctuations in production demand. In this case, an appropriate decision is among the available strategies, such as buying new machines, moving machines between the assigned positions, redesigning the production of parts, etc., in order to reduce costs. Purchase and investment, machines and the cost of reconfiguration and the cost of intranet-cellular and extra-cellular movement of parts are taken.

One of the strategic issues in the production industry is layout design, which determines the long-term efficiency of the operation, the appropriate design of the workplace makes the work flow in a line smoother, and as a result, the amount of production and the quality of the organization's production increases [7] Production systems can Reconfiguration (RMS) as effective systems in dealing with current challenges that are rapidly changing their hardware, that is, physical and software structures and logical structures to handle Changes in market needs were developed. [8] These systems were developed in a cellular production model called configurable production system

Cellular Reconfiguration (CRMS) consists of a set of dynamic cells called Re-configurable Machine Cells (RMC) where the machines are arranged in a logical rather than physical way. RMCs include re-configurable machine tools (RMTs) that are characterized by a modular structure through a set of basic and auxiliary modules that increase the number of possible tasks to perform. Partially, such machines are divided by fixed parts, that is, basic modules that represent structural entities, and by dynamic and kinematic entities, that is, auxiliary modules.

A specific set of task capabilities CRMS methodology means that RMCs are dynamic entities that evolve as RMTs are reconfigured in terms of the arrangement of auxiliary modules over the production horizon. [9].

Industrial engineers believe that no arrangement is ideal and there can always be better options, so the good or bad arrangement is a relative issue and its influence on other parameters can have different degrees. Proper arrangement makes the auxiliary modules travel shorter distances, have more security and more order prevails in the factory [10].

This research is trying to develop a mathematical optimization model based on linear programming for the dynamic management of CRMS by considering the arrangement of machines and considering the reliability. The main objective of the model is to analyze and balance efforts to reconfigure the host RMT, segment in terms of module installation and disassembly, auxiliary vs inter-cell segment flow and auxiliary module. To do this, the proposed objective function of inter-cell segment travel time Minimizes auxiliary module and reconfiguration time for installation and disassembly of auxiliary modules according to industry practice in model formulation.

Auxiliary modules are rare entities that exist in a limited amount. This is a new aspect because in existing studies [11, 12] auxiliary modules that represent the main components of RMSs are usually industrial companies. They have a set of auxiliary modules that include a number of auxiliary modules and a limited number of auxiliary module units in each type. It is very important to consider auxiliary modules as available in a limited number from an economic point of view, for example, investing in equipment and tools is very important. It affects production planning. On the other hand, at the level of performance management of processes and equipment, maintaining and improving reliability is one of the most important concerns

Engineers and managers of manufacturing industries have developed various analytical methods to evaluate and manage reliability. The use of each of these analyzes depends on the stage of the life cycle, its priority equipment among other equipment, the amount of recorded data and other such factors. It should be noted that the types of reliability analyzes are related to each other and in

Solving the problems caused by reducing the level of reliability can be used from different perspectives [13]. In the meantime, flexible production systems are considered as one of the most efficient methods used to reduce or eliminate these problems in production processes. The arrangement of production facilities is considered more than a technical solution, as a business solution that leads to Improving profitability, reducing order lead time and inventory levels, quick response to market changes, lower manpower levels, and improving production efficiency with operational flexibility have been proposed. Also, by spending a short time to design the layout of the equipment and spaces before their deployment, many damages and dis satisfactions can be avoided, such as the problems of the production units, such as the long time of the production process, the existence of bottlenecks in the production unit, and dissatisfaction.

To mitigate disruptions to employees and streamline operational changes, planning space and equipment layouts on paper offers a cost-effective alternative to physical relocation. Consequently, researchers are developing algorithms and decision-making methodologies to optimize equipment and unit arrangements. It can be implemented in the operational environment and be compatible with the conditions of the working environment. As a result, a multi-faceted analysis evaluates the changes in the overall performance of the production system that is affected by the limitation of auxiliary modules, and besides, this research tries to expand previous research on the effect of the existence of deployment limitations or Check the arrangement of machines and discuss the reliability in the assumptions of the model.

3. Dynamic model

The model is a dynamic model that considers several time periods; The number of parts and therefore the number of machines in each period is different from the previous period. Considering the difference in the number and type of parts in production transportation equipment from one period to another, in addition to the changes in the number of machines, the placement of machines in each period will also be different from the next period. Our goal in this model is to minimize the cost of both moving types of acellular and extracellular parts, as well as the cost of moving machines from one period to another and performing operations on each machine due to the layout of production facilities [6]. Considering the cost of arranging the production facilities for the movement of machines makes the model try to find an optimal arrangement for the machines in all periods in order to avoid moving the machines that have a high movement cost as much as possible and in accordance with the infra-system transportation planning. Defined in all courses to create a suitable layout for the production line. In this model, each operation of each part can only be performed on one of the machines that have the ability to perform that operation, and the ability to distribute parts that is available in previous models [7] is not available in this model. In this model, there are a number of machines of each type at the beginning. The first period is available, and if needed, the level of production space is added based on social indicators. If the number of machines required is more than the number of available machines, in this case, we will purchase machines at the beginning of each period, and if in one period, a number of machines will be purchased. If we don't need machines, they will be removed from the production space to avoid imposing the maintenance cost that we consider for the machines in the production space [8]. The movement of parts is divided into two categories, acellular and extracellular, and depending on the type of part, its cost is different. For each type, an objective function is considered so that the cost management can be implemented well. One of the innovations of the presented model is that The cost of intranet-cellular and extra-cellular movement depends on the distance and the distance traveled between two machines, and the distance between two machines depends on the positions where the machines are placed. All machines have the same dimensions and are placed in positions with the same dimensions. Machines must be placed in places where their distance from other places is clear and fixed. Here, an arrangement in several rows or, in other words, a two-dimensional arrangement is considered, which has not been used in previous works [9].

4.Modeling assumptions

Each type of piece has a specific number of operations that must be performed based on the relevant sequence.

. The execution time for all the operations of a piece on different machines that have the ability to perform that operation is known.

The amount of demand for each type of piece in each period is uncertain.

. The capacity of each type of machine is specific.

At the beginning of the first period, a number of machines of all types are available.

Fixed costs related to each machine are specific. These costs include the cost of maintaining the machines in the production area.

. The number of machines available of each type in each period is equal to the machines available in the previous period plus the machines purchased at the beginning of this period.

In this model, the number of machines is not fixed and in each period, according to the number and type of parts, and if the number of available machines is not enough for production, the machine is purchased at the beginning of the period.

The number of machines available at the level of the production space in each period is equal to the number of machines of the previous period plus the number of machines that are added to the production space from the available machines in the new period, minus the machines that are subtracted from the set of machines.

The variable cost of producing each machine to perform the operation depends on the amount of part that is allocated to that machine.

The cost of moving any type of machine between two periods is known.

The number of cells that must be formed in each period is already known, and the number of workstations for balancing is known.

The maximum and minimum cell size is specified.

All machines have the ability to perform one or more operations. For example, each operation of a part can be executed on several different machines with different processing times.

In the mathematical model, two types of equipment are considered for transportation, intercellular transportation equipment that is done through forklifts and intracellular transportation equipment that is done with gantry or overhead cranes.

The index used for the type of parts p={1,2,3…..P}

The index used for p-type segment operation k(p)={1,2,3....KP}

The index used for the type of machines m={1,2,3....M}

Index used for cell numbers c={1,2,3…..C}

The index used for the number of positions l={1,2,3…..L}

Index used to count time periods t={1,2,3…..T}

5.Objective function

The objective function includes two types of costs for the movement of parts and one movement, machines, the cost of buying and maintaining machines, as well as a machine-related production cost.

1) In the first objective function: including the cost of intranet-cell movement for each piece of type p

$$\boldsymbol{minC_1} = \sum_{T=1}^{T}\sum_{c=1}^{C}\sum_{m=1}^{M}\sum_{l=1}^{L}\sum_{m'=1}^{M}\sum_{l'=1}^{L}\sum_{p=1}^{P}\sum_{k_p=1}^{K_P} Z_{K_Pmlct}.Z_{K+1_Pm'L'Ct}\,D_{Pt}d_{LL'}IA_P \; (1)$$

$\boldsymbol{Z_{K_Pmlct}} =$

$$\begin{cases} 1 \;\; If\ the\ k-th\ operation\ of\ the\ type\ p\ piece\ is\ performed\ on \\ the\ type\ m\ machine\ located\ at\ location\ L\ and\ cell\ C\ in\ period\ t \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad Otherwise \end{cases}$$

$\boldsymbol{Z_{K+1pm'L'Ct}} =$

$$\begin{cases} 1 \quad If\ the\ k+1th\ operation\ of\ the\ p-type\ piece\ is\ performed\ on\ t \\ he\ m-type\ machine\ that\ is\ located\ in\ position\ \boldsymbol{L'}\ and\ cell\ C\ in\ period\ t \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad Otherwise \end{cases}$$

$\boldsymbol{D_{Pt}}$: **Demand quantity for each piece of type p in period t**

IA_p: Intracellular transfer reliability for each p-type fragment using intracellular equipment

$\boldsymbol{d_{LL'}}$**:The distance between the two positions L and L'**

$\boldsymbol{k_P}$: $\boldsymbol{The\ index\ used\ for\ p-type\ segment\ operations\ k_P}$ **={1,2,3…..K_P}**

K_P: The number of the last operation of the type p piece

P : The number of the last operation of the type p piece p={1,2,3….. P}

m : Used for MACHINE type m

m={1,2,3…..M}

m'´: Used for machine type

M: The last type of car

l: the index used for the number of positions

l={1,2,3…..L}

l′:used for the position number l^´

L: Number of the last positions

c: The index used for cell numbers

c={1,2,3…..C}

C: Number of the last cell

t: the index used to count time periods t={1,2,3…..T}

T: Number of the last time periods

2) The second objective function: including the cost of moving between cells for each piece of type p

$$minC_2 = \sum_{T=1}^{T}\sum_{c=1}^{C}\sum_{c'\neq 1}^{C}\sum_{m=1}^{M}\sum_{l=1}^{L}\sum_{\boldsymbol{m'=1}}^{M}\sum_{\boldsymbol{l'=1}}^{L}\sum_{p=1}^{P}\sum_{k_p=1}^{K_P} Z_{KPmlct}.Z_{K+1Pm'L'c't} D_{Pt}D_{LL'}.IE_P \ (2)$$

$\boldsymbol{Z_{K_P mlct}} =$

$$\begin{cases} 1 \ \ If\ the\ k-th\ operation\ of\ the\ type\ p\ piece\ is\ performed\ on \\ the\ type\ m\ machine\ located\ at\ location\ L\ and\ cell\ C\ in\ period\ t \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad Otherwise \end{cases}$$

$\boldsymbol{Z_{K+1_P m' L' c' t}} =$

$$\begin{cases} 1 \ \ If\ the\ k+1th\ operation\ of\ the\ p-type\ piece\ is\ performed\ on\ t \\ he\ m-type\ machine\ that\ is\ located\ in\ position\ \boldsymbol{L'}\ and\ cell\ c'\ in\ period\ t \\ 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad Otherwise \end{cases}$$

IE_p: Reliability of inter-cell handling for each p-type part using intranet-workshop transport equipment

In the third objective function: including the transportation cost for each

δ_m: cost of movement for each type m machine from one period to the next period

4) The fourth objective function is the cost of buying machine

$$minC_4 = \sum_{t=1}^{T}\sum_{m=1}^{M}\gamma_m\, N_{mt}^{P} \ (4)$$

N_{mt}^{P}: The number of machines of type m added to the available machines in period t

γ_m: purchase cost of each type m machine

5) In the fifth objective function: it includes the cost of maintaining machines

3) $minC_5 = \sum_{t=1}^{T}\sum_{m=1}^{M}\alpha_m\, N_{mt}^{U}$ (5**type m machine from one period to the next period**

4) $mC_3 = 1/2(\sum_{t=1}^{T}\sum_{l=1}^{L}\sum_{m=1}^{M}\delta_m\,|\sum_{c=1}^{C}W_{mlct} - \sum_{c=1}^{C}W_{mlct+1}|$ (3)

$\boldsymbol{W_{mlct}} =$

$$\begin{cases} 1 & If\ the\ machine\ of\ type\ m\ is\ located\ in\ cell\ c\ and\ location\ L\ in\ period\ t \\ 0 & Otherwise \end{cases}$$

)

α_m: maintenance cost of type m machine in each period

N_{mt}^{U}: the number of machines of type m to be arranged in the course

5) In the sixth objective function: it includes the production cost related to the machine

6) $minC_6 = \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{l=1}^{L}\sum_{m=1}^{M}\sum_{c=1}^{C}\sum_{k_p=1'}^{K_p} Z_{k_pmlct}\, D_{Pt}a_{k_pm}\beta_m$ (6)

β_m: The cost of performing an operation on machine type m for one time period

$$a_{k_pm} = \begin{cases} 1 & If\ the\ kth\ operation\ of\ piece\ p\ can\ be\ done\ on\ machine\ type\ m \\ 0 & Otherwise \end{cases}$$

As for the restriction, it is

$$ZZ_{kpmlm'l'ct} \geq 2 - \ Z_{kpmlct} + Z_{k+1pm'l'ct}$$

$$ZZ_{kpmlm'l'ct} \geq \ Z_{kpmlct}$$

$$ZZ_{kpmlm'l'ct} \geq Z_{k+1pm'l'ct}$$

$$\sum_{c}^{C} W_{mclt} - \sum_{c}^{C} W_{mclt+1} = WP_{mlt} - WM_{mlt} \qquad \forall m \in M, \forall l \in L, \forall t \in T$$

Considering the multi-objectiveness of the mathematical model and using the approach of weighting the objectives of the mathematical model, it is developed as a single-objective model and the model is evaluated accordingly

6.Solve the model

"To prove our model works, we tested it with several examples using computer software like Maple, Matlab, and GAMS. Because our model tries to achieve multiple goals at once (multi-objective), we simplified it by combining those goals into a single one, making it easier to solve.

Example 1:

This test had a huge number of variables (52,585) and constraints (35,709). Think of variables as things we need to decide, and constraints as rules we must follow. Matlab software found the best solution in 52 hours, 35 minutes, and 20 seconds.

Examples 2 and 3:

These tests were even bigger, with hundreds of thousands of variables and constraints. GAMS software solved these in about 13 and 18 hours respectively.

Example 4: Dynamic Model

This test was special because it changed over time. Imagine a factory where the number of machines and parts changes each month. Our model aimed to minimize several costs: Moving parts within and outside the factory. Moving machines between different time periods. The cost of processing parts on each machine. The model smartly decides where to place machines to reduce unnecessary moves, especially costly ones. Each part's operation can only be done on specific machines' We can buy more machines if needed, or remove unused ones to save on maintenance costs. In essence, we put our model through tough tests to show it can handle complex problems and find efficient solutions, especially when things change over time.

To show the correctness of the presented model, some numerical examples have been solved using maple software. Due to the multi-objectiveness of the mathematical model, using the approach of weighting the objectives of the mathematical model, it has been developed as a single-objective model and the evaluation of the model has been done based on it. Therefore, the validation of the mathematical model is as follows. In the first example, the number of model variables is equal to 52585 variables and the number of its constraints is equal to 35709 constraints. After 52:35:20, the optimal answer has been obtained with Matlab software.

The second example has been evaluated according to the larger dimensions. The number of variables in this model in this example is equal to 338184 variables and the number of its restrictions is equal to 338071 restrictions. The optimal answer was obtained with Games software after 13:21:33. . The number of model variables in the third example is equal to 287424 variables and the number of its constraints is equal to 242484 constraints. The optimal answer has been obtained after 18:21:33 with Games software.

In the fourth example, the model is a dynamic model in which several time periods are considered and the number of parts and, accordingly, the number of machines in each period is different from the previous period. The difference in the number and type of parts from one period to the next, in addition to the change in the number of machines, causes the position of the machines to be different in each period compared to the next period.

Our goal in this model is to minimize the cost of moving two types of intranet-cellular and extra-cellular parts, as well as the cost of moving machines from one period to the next and the cost of performing operations on each machine. Considering the cost of moving the machines makes the model try to find an optimal arrangement for the machines in all the periods in order to avoid moving the machines that have a high moving cost as much as possible. In this model, each operation of each part can only be done on one of the machines that have the ability to perform that operation, and the ability to distribute parts that is available in previous models is not available in this model. In this model, a number of machines of each type are available at the beginning of the first period, which can be added to the level of production space if needed.

If the number of required machines is more than the number of available machines, in this case, we will buy machines at the beginning of each period, and if we do not need a number of machines in a period, they will be removed from the production space to avoid imposing maintenance costs. For the existing machines at the level of the production space, we consider it to be avoided.

Table 1 shows the set of parameters of four examples and Table 2 shows the information related to the objective function of the examples.

Table 1. A set of parameters of uncertainty example 1

amount	parameter	amount	parameter
U(1,10)$	β_m	U(0,1000)	D_{pt}
U(1000,2000)$	γ_m	U(0,1)	t_{kpm}
3	k_p	1,2	$\sum a_{kpm}$
3	B_U	50$	IEp
2	B_L	5$	IAp
2	C	U(500,1000)$	δ_m
4	M	U(1000,2000)$	α_m
3	P	2	T

Table 2. A set of parameters of uncertainty example 2

amount	parameter	amount	parameter
3	k_p	2,3	$\sum a_{kpm}$
3	B_U	50$	IEp
2	B_L	5$	IAp
3	C	U(500,1000)$	δ_m
5	M	U(1000,2000)$	α_m
5	P	2	T

we can infer the types of advanced technologies and information technology used within the context of this model.

Information Technology (IT) in this context is crucial for handling the large amounts of data and complex calculations involved. The text mentions using Maple, MATLAB, and GAMS software. These are specialized tools. A numerical computing environment widely used in engineering and science for simulations, data analysis, and algorithm development. (General Algebraic Modeling System) Specifically designed for modeling and solving large-scale optimization problems, exactly the kind described in the text.

Solving problems with hundreds of thousands of variables and constraints requires significant computing resources. This implies the use of powerful computers, potentially high-performance computing clusters, to handle the computational load. This is a key aspect of IT. While not explicitly stated, managing the input data for the model (part types, machine capabilities, costs, etc.) and storing the results would likely involve databases or other data management systems, which fall under the umbrella of IT.

The "advanced technology" refers to the sophisticated modeling techniques and the subject of the model itself: The core of the model is likely based on advanced optimization algorithms (e.g., linear programming, mixed-integer programming, dynamic programming). Finding the "optimal answer" for such complex problems relies on these algorithms. The model itself is a sophisticated piece of applied mathematics. Translating a real-world production problem into a set of equations and constraints is a complex task and a form of advanced technology in itself. The fourth example specifically mentions a "dynamic model." This means the model considers how the system changes over time (different numbers of parts and machines in different periods). Dynamic modeling is a more advanced technique than static modeling.

Table 3. A set of parameters of uncertainty example 3

amount	parameter	amount	Parameter
3	k_p	2	$\sum a_{kpm}$
3	B_U	50$	IEp
2	B_L	5$	IAp
3	C	U(500,1000)$	δ_m
5	M	U(1000,2000)$	α_m
4	P	2	T

Table 3. A set of parameters of uncertainty example 4

amount	parameter	amount	Parameter
3	k_p	2,3	$\sum a_{kpm}$
3	B_U	50$	IEp
2	B_L	5$	IAp
3	C	U(500,1000)$	δ_m

4	M	U(1000,2000)$	α_m
5	P	2	T

Table. 4 of the final costs of uncertainty

zbest	The cost of buying a machine	machine maintenance cost	Intercellular cost	Intracellular cost	The cost of moving the machine	Operation cost	Example
145409	83000	14900	-	12760	425	34409	1
361180	122000	12200	133150	31410	-	62420	2
186554,1	114000	22800	-	13800	850	35954,1	3
206073	103000	20600	-	27500	-	54973	4

For the first example, as it can be seen, the cost that is considered for the movement of machines makes the machines to be placed in a suitable arrangement and less to be moved from one period to the next. How to arrange the machines as well as the arrangement of the cells is shown. As it can be seen from the figure, since there was a demand for part 3 in the first period and this part needed machine 4 to perform its operations, therefore machine 4 was purchased in the first period and in the next period when this machine is not needed from The level of production space has been removed to avoid incurring maintenance costs. In this model, the number of machines increases or decreases in each period according to the demand, so no machine is ever left unused. One of our problems in presenting this model is obtaining the answer in large or even medium sizes, which is due to the ability to spread the demand on different machines. In this example, in the first period, part of the demand for parts 1 and 2 is produced in the first cell, and all It is completely done in this cell, and all the demand for parts and part of the demand for parts 1 and 2 are produced in the second cell, and all its operations are done completely in this cell. In the second period, the demand for parts 1 and 2 is divided in the first and second cells.

or the second example, as it can be seen, the cost of moving the machines causes the machines to be placed in a suitable arrangement and to be moved less from one period to the next. The location of the machines as well as the cells is completely flexible from one period to the next period, and for example, for this particular example, the location of the cells changes from one period to the next period, which makes it possible to avoid the cost of moving the machines from one location to another. Avoid other places. The machines that are supposed to perform successive operations of parts are brought together and placed in one cell as much as possible so that the operator of those machines can more easily service those cells and machines so that this operation can be done with the lowest cost.

In the third example, it can be seen that the cost that is considered for the movement of the machines makes the machines to be placed in a suitable arrangement and less to be moved from one period to the next. Also, the location of the machines and also the cells from one period to the next period are completely It is flexible and, for example, for this specific example, the location of the cells changes from one period to the next, which prevents the cost of moving machines from one place to another, and in this example, only in one case of moving. We had a car, and in the rest of the cases, by changing the configuration of the cells, the movement of the cars has been prevented.

Table 3 shows the number of parts and their processing location in each operation. The distribution of parts according to the handling cost causes that in addition to the parts for each operation, they look for a machine that performs this operation with the lowest cost. Bring the machines that are supposed to perform successive operations of the parts together and place them in one cell as much as possible so that the operator of those machines can more easily service those cells and machines.

Table 3 information related to the operation in the first and second periods First period

Machine info			P1			P2			P3			P4		
C	M	L	1	2	3	1	2	3	1	2	3	1	2	3
C1	M1	7				352	146	352						
	M5	4					206							
C2	M2	1			200									
	M2	3												
	M3	2	200	200										
C3	M1	8					348	348			300			
	M4	5				348			300	300				

Second period

Machine info			P1			P2			P3			P4		
C	M	L	1	2	3	1	2	3	1	2	3	1	2	3
C1	M2	3		26	105	352	146	352			700			273

	M3	2	105	79								273	273	
	M4	6							700	700				
C2	M2	1			395							27		
	M5	4	395	395									27	27
C3	M1	7												
	M1	8				250	250	250						

For the fourth example, the cost that is considered for the movement of the machines makes the machines to be placed in a suitable arrangement and to be moved less from one period to the next, and the location of the machines as well as the cells is completely flexible from one period to the next. And for example, for this particular example, the location of the cells changes from one period to the next. In this example, in the first period, one of the m=1 type machines, in the second period, one of the m=2 type machines and one of the m=3 type machines and the third period, two m1 type cars remained unused.

In this example, in the first period, all the demand for parts 1 and 2 are produced in the first cell, and all its operations are completely performed in this cell, and all the demand for parts 3, 5, and 6 are produced in the second cell, and all its operations are performed in the same cell. It is completed in the same cell in the second period of demand for parts 1, 3, 4 and 6 in the first cell, the demand for piece 2 is produced in the second cell, and finally, in the third period, the demand for piece 4 is produced in the first cell and demand Parts 1, 3, 5 and 6 are fulfilled in the second cell.

Also, Figure 1 shows the location of the machines in the cells and the overall shape of the positions in the balance performed in the production line It shows different courses.

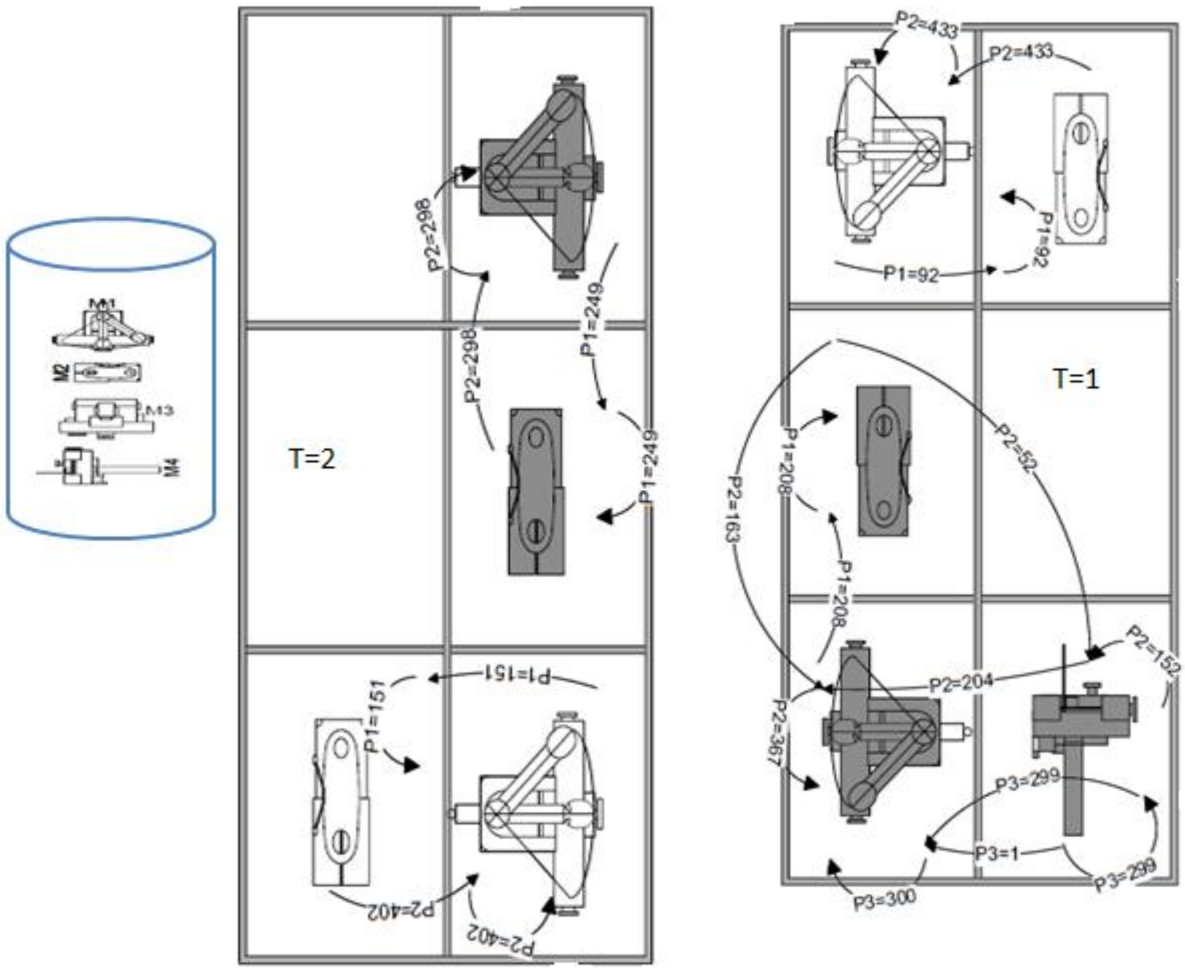

Figure 1. Configuration of cells and arrangement of machines: a) first example

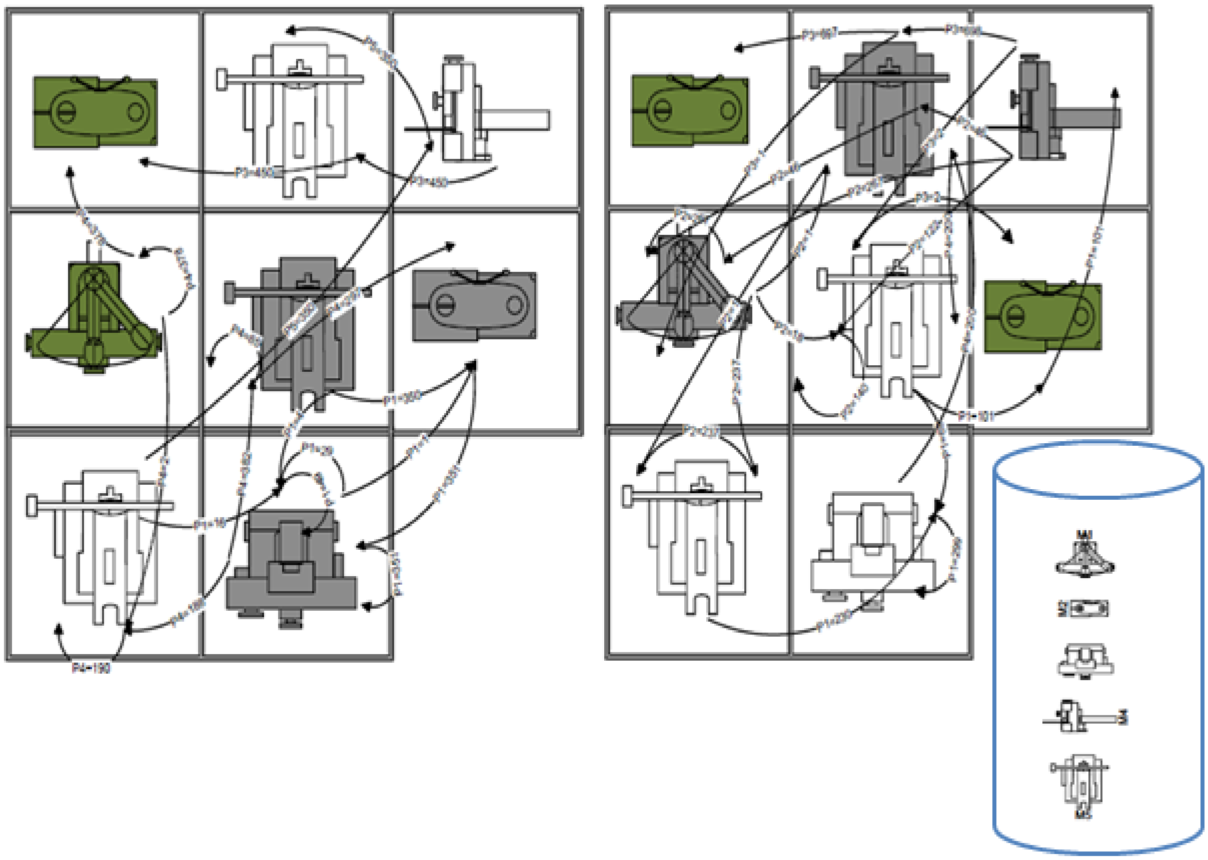

Figure 1. Configuration of cells and arrangement of machines: (b) second example

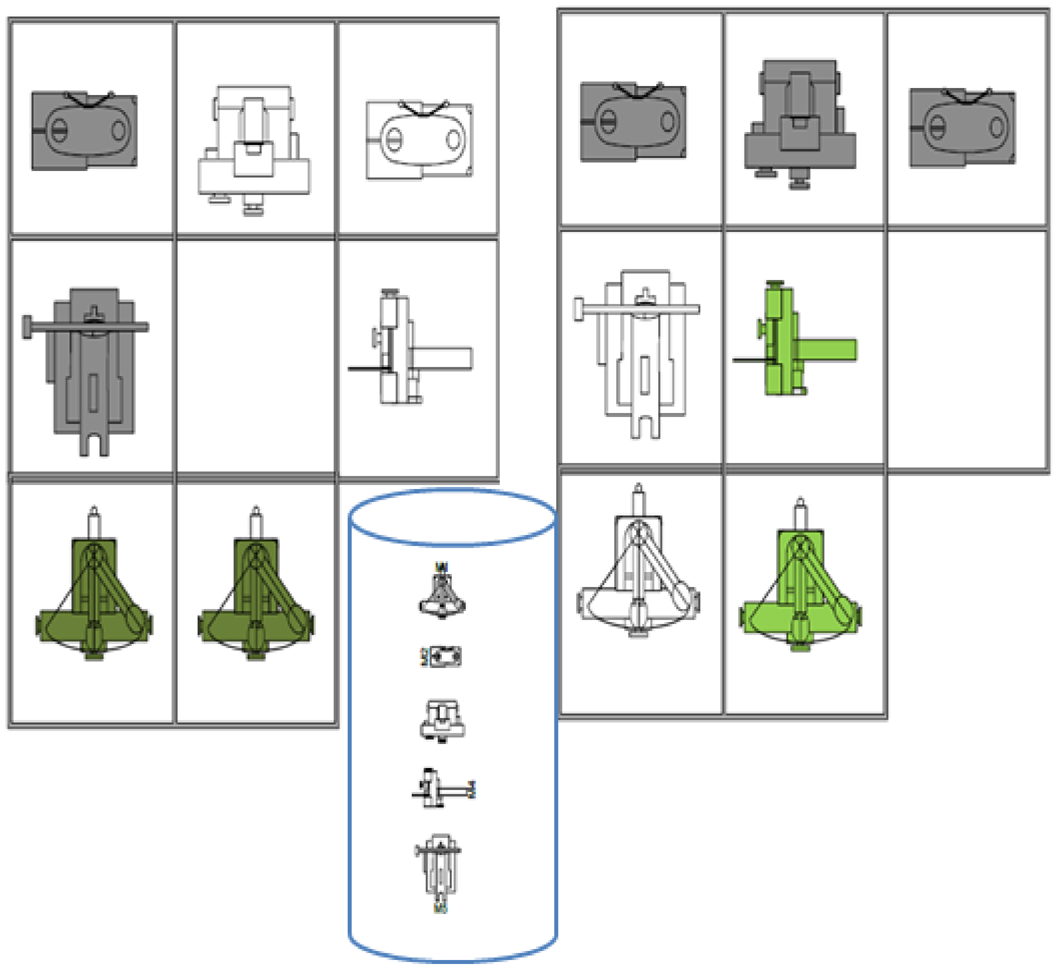

Figure 1. Configuration of cells and arrangement of machines: (c, third example,

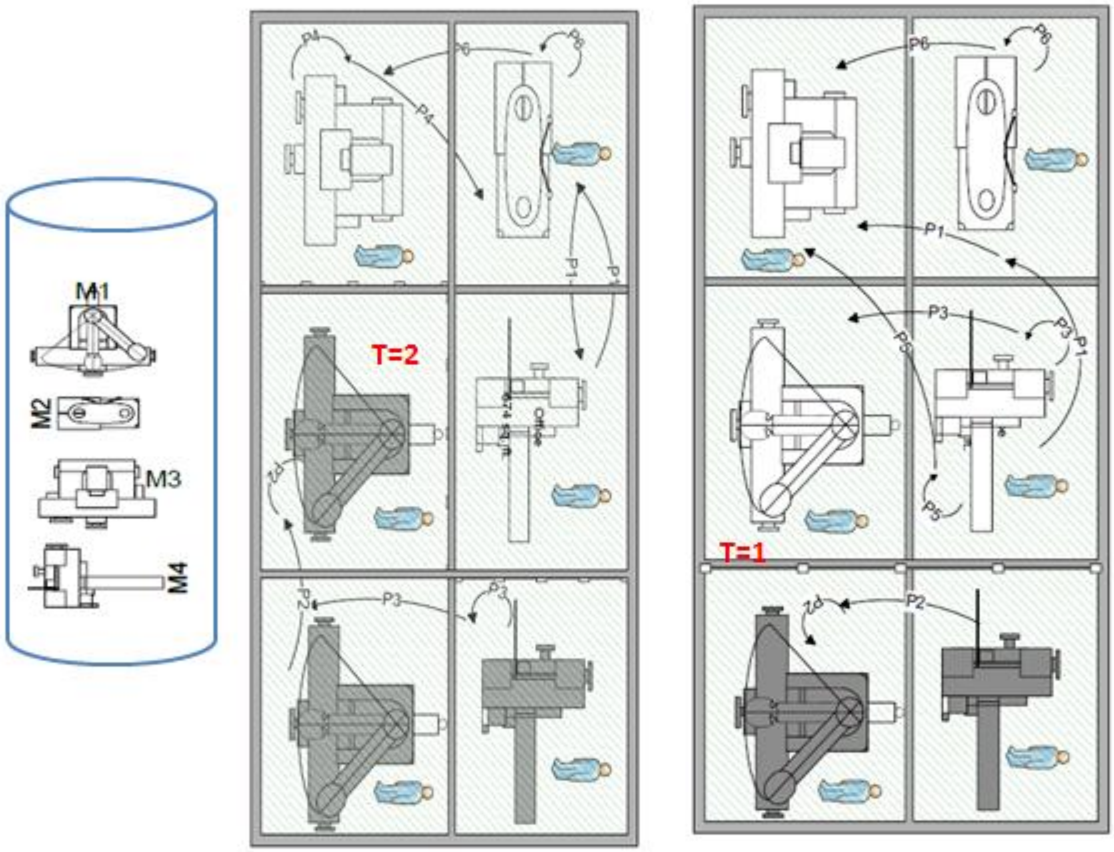

Figure 1. Configuration of cells and arrangement of machines:, d) fourth example

7.Conclusion

Based on the results obtained from the simulation results, we can confirm the importance of using simulation to investigate ' a cell structure, packaging and intracellular machinery to reduce costs. The number of transmission units, machine implementation costs, and costs of transportation, purchase, and maintenance of machines in the system increase throughput of the system, which can lead to imbalance in the whole system. One of the advantages of this model is that over clustering machines, it tries to minimize the interactions between nodes in as much as possible, thereby increasing the throughput of the nodes.

Consider multi-lane layout, cell layout and cost estimates, machine rotation and lifting costs depending on the distance between the machines distinguishes the objects compared to other examples, this model is an integer multi- dimensional. An example of this research protocol with a dynamic resource allocation problem is presented. Further investigation could lead to new ways of addressing the questions in future research with different experimental designs and e results of the high-throughput model. [1] Sharma A, Sharma RK. Model and analyze the drivers of successful implementation of cellular manufacturing systems.

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