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제약이론을 활용한 재구성가능 생산시스템의 레이아웃 설계

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Design of a System Layout for Reconfigurable Manufacturing System with Theory of Constraints

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ABSTRACT

This paper presents a systematic approach for design of timely and proper layouts of a manufacturing system facilitating reconfigurability, referred to as a reconfigurable manufacturing system. A proper methodology for design of a system layout is required for reconfiguration planning – adding or removing machines for supplying the exact capacity needed to fulfill market demands, as well as minimizing the cost of adding new machines. In this paper, theory of constraints is used to make reconfiguration manufacturing systems more cost-effective and efficiency. The proposed approach is validated by using a real industrial case. This paper suggests that the proposed study should be performed concurrently with the design of a new manufacturing system.

Key Words: Reconfigurable system design, Reconfigurable manufacturing system, Theory of constraints, Scalability

1. Introduction

Dynamic and unpredictable market changes make manufacturers facing more challenges than before. Manufacturers should change the manufacturing systems to meet customer's dynamic needs. Also making a good quality product at low cost and rapid response for dynamic market changes are most important thing in these days.

In order to be competitive in manufacturing environment, reconfigurable manufacturing systems is the one of the solutions which can adapt to expected or unexpected demand changes through systems. The purpose of RMS (Reconfigurable Manufacturing Systems) is supplying capacity to meet their demand when needed and where needed. So, the production capacity should be scaled to the demand continually in order to always be in a profitable state.

The objective of the manufacturing company is to increase throughput, decrease inventory and operating expense in such a way as to increase profit, return on investment and cash flow. When using TOC (Theory of Constraint) in company, It can satisfy manufacturers various objectives. Company adopting the TOC indicates that it has aided in reducing lead time, cycle time and

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inventory while improving productivity and quality.

TOC is an organized way to approach a business operation and to try to improve it. The TOC allows the managers involved in the process to focus on the constraints in the process. TOC can increase the ability to achieve the system's goal for manufacturers that means increased net profits and return on investment now and in the future.

Wang and Koren[1] proposed a scalability planning to minimize the number of machines needed to meet a new market demand in RMS. In our study, we combine two concepts, RMS and TOC so as to minimize the cost of adding new equipment or machines. When manufacturing company uses RMS to adapt flexible demand and TOC to improve the process, it can survive for the new era of global competitiveness characterized by increasing product variety.

This paper organized as follows. In section 2, the concept of RMS and TOC is described more detailed. In section 3, a mathematical model is constructed in order to support the reconfigurable system design which minimizes the cost of adding new equipment or machines, followed by notations and assumptions. Constraints with TOC are represented in this section too. Section 4 presents case study to illustrate our objective function and get numerical results. Section 5 summarizes this paper and gives some conclusions.

2. Literature Review

2.1 Reconfigurable Manufacturing System

Manufacturing systems have rapidly evolved driven by aggressive competition on a global scale, customers who are more educated and demanding, and a quick pace of change in product and process technology. Traditional manufacturing systems – both dedicated manufacturing lines (DMLs) and flexible manufacturing system (FMS) – are not well suited to meet the requirements dictated by the new competitive environment.

DMLs are based on inexpensive fixed automation that produces a company's core products or parts over a long period and at high volume, driven by the economy of scale[2]. Each dedicated line is typically designed to produce a single part at a high rate of production achieved by utilizing all tools simultaneously. When product demand is high, the cost per part is particularly low. DMLs are cost effective as long as they can operate at full capacity, but with increasing pressure from global competition and overcapacity worldwide, dedicated lines usually do not operate at full capacity.

The concept of flexible manufacturing systems (FMS) was then introduced to satisfy the need for mass customization and greater responsiveness in products changes, production technology, and markets[3]. Typically, FMS consist of general-purpose computer-numerically-controlled (CNC) machines and other programmable forms of automation. Because CNC machines are characterized by single-tool operation, FMS throughput is much lower than that of a DML. The combination of high equipment cost and low throughput makes the cost per part using FMS relatively high. Similarities between parts in design and/or manufacture were used to achieve economy of scope.

The reconfigurable manufacturing concept (RMS) has emerged in the last few years in an attempt to achieve changeable functionality and scalable capacity[4]. It proposes a manufacturing system where machine components, machines, cells, or material handling units can be added, removed, modified, or interchanged as needed to respond quickly to changing requirements. Such a fully reconfigurable system does not yet exist today but is the subject of major research efforts around the world, with special emphasis on the hardware and machine control aspects.

Current market developments are characterized by imponderability, which mostly cannot be influenced by the companies[5]. Koren states that a fast, specific and economic adjustment of the systems regarding structure, capacity, technology and function requires Reconfigurable Manufacturing Systems (RMS)[4,6] for which he offered comprehensive solutions. Instead of providing a general flexibility through the life time of equipment with built-in high functionality as in FMS, RMS provides customized flexibility[7]. RMS aims at combining a scalable output and an adjustable functionality with a minimum lead time and high productivity. RMS is designed to cope with situations where both productivity and the ability of the system to react to changes are of vital importance as seen in Fig. 1. In summary, an ideal RMS comprehends the advances of DMS and FMS[6]. As summarized in Table 1, Reconfigurable Manufacturing Systems (RMS) constitutes a new

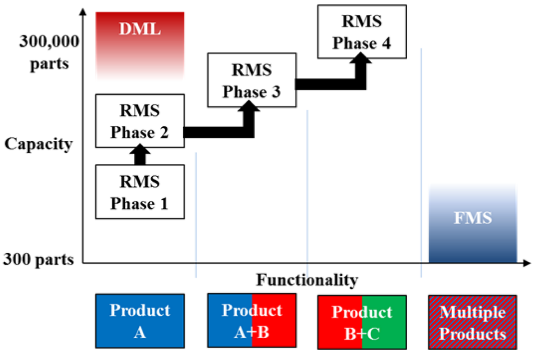


Fig. 1 Capacity and functionality changing in response to market changes

class of systems characterized by adjustable structure and design focus. While Fig. 1 shows the capacity and functionality difference between DML, FMS, and RMS[8]. RMS are marked by six core reconfigurable characteristics, as summarized below[9].

(1) Customization (flexibility limited to part family)
System or machine flexibility limited to a single product family, thereby obtaining customized flexibility.

(2) Convertibility (design for capacity changes)
The system is able to easily transform the functionality of existing systems and machines to suit new production requirements.

(3) Scalability (design for capacity changes)
The system is able to easily modify production capacity by adding or subtracting manufacturing resources (e.g. machines) and/or changing components of the system.

(4) Modularity (components are modular)
The compartmentalization of operational functions into units that can be manipulated between alternate productions schemes for optimal arrangement.

(5) Integrability (interfaces for rapid integration)
The ability to integrate modules rapidly and precisely by a set of mechanical, informational, and control interfaces that facilitate integration and communication.

(6) Diagnosability (design for easy diagnostics)
The system is able to automatically read the current state of a system to detect and diagnose the root causes of output product defects, and quickly correct operational defects.

Table 1 RMS systems combine features of DMS and FMS

	DML	FMS	RMS
System structure	Fixed	Changeable	Changeable
Machine structure	Fixed	Fixed	Changeable
System focus	Part	Machine	Part family
Scalability	No	Yes	Yes
Flexibility	No	General	Customized
Simultaneously operating tools	Yes	No	Possible
Productivity	Very high	Low	High
Cost per part	Low	Reasonable	Medium

Customization, scalability and convertibility[10] are critical reconfiguration characteristics. Modularity, integrability, and diagnosability allow rapid reconfiguration, but they do not guarantee modifications in production capacity and functionality. Customization, an essential RMS characteristic, is based upon design for a part family or a product family, a concept already mentioned by other researchers[11].

2.2 Theory of Constraint

After many years of development, the TOC has many distinct applications and are usually applied to running and improving an organization. In the late 1970's, the Israeli physicist Eliyahu Moshe Goldtratt, developed a method for production scheduling and later turned to educate people on the principles of TOC[12]. The central idea in the TOC philosophy is that any company/organization has a constraint (or a number of constraints) which dominate the entire system, that limits a company's ability to achieve a higher level of performance. The constraint can be solved by using the applications of TOC, problem solving and management tools, called; the five focusing steps, the Thinking Processes and throughput accounting[13]. The core concept of TOC is that every process has a constraint and that total process throughput can be improved by improving the constraint; only improvements of the constraint will further the goal (achieving more profit etc.)[14]. The five focusing steps include: step 1. Identify (identify the current constraint), step 2. Exploit (make improvements to the throughput of the constraint by using existing resources), step 3.

Subordinate (review other activities in the system so they are aligned with and support the needs of the constraint), step 4. Elevate (if the constraint still exists, consider what further actions can be taken to eliminate the constraint until it has been broken, until it has moved somewhere else), step 5. Repeat (the five focusing steps are a continuous improvement cycle)[14,15].

The thinking process are developed for complex systems like manufacturing lines, it is based on cause and effect tools. First identify the undesirable effects and then solve it by implementing new ones. Following questions has to be considered during the thinking process: What needs to be changed? What should it be changed to? What actions will cause the change? The throughput accounting is a method of simplifying and measuring what matters most in an organization so the company always working towards achieving higher profits and cash flow. In accounting to see if the company is achieving its goals three questions needs answer: 1. How much money is my company generating? 2. How much money is actually captured by my company? 3. How much do I spend to operate my company? In throughput accounting these questions are turned into following TOC Performance measures: Throughput (the rate at which the system generates new money through sales), Inventory (money that is tied up in physical tings, product inventory, equipment etc.) and Operating Expense (money spent to create throughput)[16].

TOC have many types of constraints: Physical constraints (machine capacity, material availability, space availability etc.), Market constraints (demand for companies products and services is less than capacity of organization, or not in desired proportion), Policy constraint (includes entire system of measures and methods and even mindset that governs the strategic and tactical decisions of the company), Mindset constraints (a constraint if through process or culture of the organization blocks implementation of methods required to achieve goals), Measures constraints (a constraint if the company's behavior are incongruous with the organizational goals) and Methods constraints (a constraints when procedures and techniques use result in actions incompatible with the organizational goals). Steven and Victoria[16] conducted a research by using TOC to achieve low cost using cost constraints.

3. Problem formulation of scalability planning problem

In this section, we present a practical method to determine the most cost effective system reconfiguration to satisfy a new market demand. To evaluate the adding cost of system scalability planning, many factors need to be taken into consideration. When reconfiguring an existing manufacturing system, reconfiguration planning and system design rebalancing attempts are needed to maximize the capacity of systems, and therefore, minimize the cost of adding new equipment or machines. Buying new machines can be extremely expensive. The process of adding new machines need long times to setup or rearrange the layout and also stopping the production processes need time. We consider processing cost and machine cost in our objective function. TOC constraint will be added to make more realistic and more profit in the present and future.

3.1 Notations and assumptions

To perform system reconfigurable system design for reconfiguration planning, the following notations and assumptions are used.

Notations:

- L Number of stages
- K Number of machines type
- N_i Number of machines in each stage, $i = 1, 2, \ldots, L$
- $M[i]$ Number of new machines added in each stage, $i = 1, 2, \ldots, L$; $M[i] > 0$ for adding machines, and $M[i] < 0$ for removing machines from systems.
- C_j Processing cost for new machine $j = 1, 2, \ldots, K$
- B_j Buying cost for new machine $j = 1, 2, \ldots, K$
- H Company budget

Assumptions:

(1) A multi-stage system is considered. Parts are moved from one stage to another through conveyors and delivered to different machines within a stage using gantries.

(2) The number of stages must remain unchanged during any reconfiguration process. This is to keep the system setup plan unchanged in

order to avoid major adjustments of process plans, thereby minimizing the impact of system reconfiguration on product quality.
(3) All the machines within the same stage perform exactly the same sequence of tasks.
(4) There are reserved spaces for adding new machines in the stages and material handlers can be extended to deliver parts to the newly added machine.
(5) The system throughput will be the same for whatever stage the machines are being added/removed.
(6) Company budget doesn't include maintenance fee for added machines.

3.2 Objective function

The objective function of reconfigurable planning is to minimize the cost of adding new machines needed to meet a mew market demand. This can be expressed as follows.

$$\text{Minimize } \sum_{j=1}^{K}\sum_{i=1}^{L}[(N_i+M[i])\times C_j]+(M[i]\times B_j) \tag{1}$$

3.3 Constraints

Our objective function is subject to the following constraints.
(1) Throughput constraint:
After the new machines are added, the system throughput must be equal or larger than the new market demand.
(2) Cost constraint:
Buying cost of new machines cannot exceed of a certain budget H.

$$\sum_{j=1}^{K}\sum_{i=1}^{L}M[i]\times B_j\leq H \tag{2}$$

4. Case Study

This section presents a case study that is reflected from Wang and Koren[1] to examine and validate the proposed approach. Assume that there are 141 features on the part, which can be grouped into 43 machining tasks, including milling, drilling, boring, spot facing, and tapping. The total time needed for the rough machining is 1019 s. The machines used for all stages are four-axis CNC machining centers which are capable of completing all the machining tasks. As for additional point, the company is able to select between two types of machines to be added in the configuration; machine A and machine B. Both machines have different price and specifications. The case study is conducted in order to show how the RMS configuration works and how to calculate the reconfiguration cost for each demand period. The reconfiguration cost is calculated by summing machine buying cost, machine adding cost, and machine processing cost.

The cost of machine A is \$40,000, and same with original machine which are already set on the line. The cost of machine B is \$50,000 which is more expensive than machine A, and has 120% utilization compare to machine A. To satisfy new demand, we can choose machine A or B. Machine B is more expensive than machine A but have good utilization so if the demand is not satisfied with machine A, we can choose machine B which is more profitable. Therefore, by using the proposed approach, a company is able to select/combine between both types of machine to satisfy the new demand, which the unit for demand is in JPH (jobs per hour). There are 10 periods for systems reconfigurable planning, one period means one month. The demand will be different per period, so the number of adding machine will be different.

Processing cost is cost to reconfigure the machines. Reconfiguration process requires adding and removing machine, therefore it needs cost to setup and re-setup machines whenever there are newly added or removed machines. Assume that the cost of adding machine A is \$29.792 and cost of adding machine B is \$37.24, cost of processing machine A is \$7.885 and cost of processing machine B is \$9.462.

4.1 Baseline configurations

To achieve the best system throughput, each system configuration needs its corresponding setup plan. There are 121 CNC machining centers which are used as baseline systems. From there, we build four system configurations to study the reconfiguration planning shown in Fig. 2; 2×6, 3×4, 4×3 and 6×2. In this paper, configuration 1×12 and 12×1 are not considered, since the focus of this research is RMS which is multi-stage manufacturing system. Manufacturing system with single stage or multiple stages with one machine in each stage would be properly considered

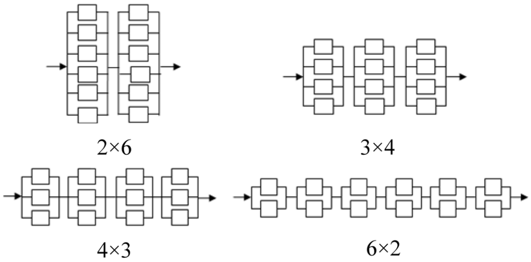


Fig. 2 Design of system configurations

Table 2 Comparison result of system throughput

System configurations	Number of machines added	System throughput (JPH)		
		Initial	New	Difference
3×4	0	33.1	33.1	0.0
	1	35.9	35.9	0.0
	2	39.1	38.6	0.5
	3	41.8	41.4	0.4
	4	44.0	44.1	-0.1
	5	47.1	46.9	0.2
4×3	0	30.9	30.9	0.0
	1	34.0	33.5	0.5
	2	36.6	36.1	0.5
	3	38.9	38.6	0.3
	4	41.8	41.2	0.6
	5	44.2	43.8	0.1
6×2	0	27.9	27.9	0.0
	1	30.1	30.2	-0.1
	2	32.3	32.6	-0.3
	3	34.6	34.9	-0.3
	4	37.1	37.2	-0.1
	5	39.3	39.5	-0.2

as standard serial assembly line.

For each configuration, reconfigurations for adding up to 5 machines to existing systems are calculated. Before calculating the new machines adding, we need to clarify whether the calculation of system throughput from ours is matched with the initial calculation from reference paper Wang and Koren[1]. Table 2 summarizes the comparison between both calculation results. Table 3 shows the system throughput of each configuration when 1-5 machines A are added to the baseline system, by using data from our calculations. The calculations of the scalability for each configuration resulted in that the 2×6 configuration has the highest capacity and thereby the highest throughput. For example, by adding one machine from supplier A, with machine utilization of 100% (+1 machines), to the baseline system the throughput increases from 35.3 JPH (jobs per hour) to 38.2 JPH.

Table 4 summarizes the system throughput of all configurations when new machines B are added, with higher price and higher machine utilization as well. By using the configuration with the highest capacity/throughput and choose the supplier with low machine buying cost, but still are able to meet the demand, gives us the minimization of adding new machines. Our model can handle more supplier choices, but to simplify we only consider two suppliers; A and B. When removing machines from the baseline of 12 machines with utilization 100%, same as machines from supplier A, we only consider supplier A.

4.2 Results of reconfigurable system design for reconfiguration planning

For applying our model we use 10 periods with randomly created demand between 30-50 JPH, which is shown in Table 5. For example in the

Table 3 System capacity of each configuration when new machines A are added

	System throughput (JPH)					
Number of machines added	0	1	2	3	4	5
2×6	35.3	38.2	41.2	44.1	47.1	50.0
3×4	33.1	35.9	38.6	41.1	44.1	46.9
4×3	30.9	33.5	36.1	38.6	41.2	43.8
6×2	27.9	30.2	32.6	34.9	37.2	39.5

Table 4 System capacity of each configuration when new machines B are added

	System throughput (JPH)					
Number of machines added	0	1	2	3	4	5
2×6	35.3	38.8	41.8	44.7	47.7	50.6
3×4	33.1	36.4	39.2	41.9	44.7	47.5
4×3	30.9	34.0	36.6	39.2	41.7	44.3
6×2	27.9	30.7	33.0	35.4	37.7	40.0

Table 5 Demand

Period	Demand (JPH)
1	46
2	50
3	38
4	44
5	37
6	40
7	32
8	33
9	50
10	35

demand in period 1 for configuration 2×6 is 46 JPH. There are several options to satisfy the demand; by adding a number of machine A or machine B or combination of both machines. We need to carefully select the options to be good enough to satisfy the demand as close as possible, in order to supply the material exactly how much needed as well as minimizing the cost of adding new machines. In period 1 with demand of 46 JPH, the best option is to add 4 machines A and we can get throughput 47.08 JPH. In period 2 with demand of 50 JPH, we need to add 5 machines A to the baseline, which means that we need to buy one more machine A and add that new machine from previous setup in period 1. Table 6-Table 9 summarizes the optimal combination of adding/removing machines to meet the demand for each period and the total cost calculated for each configuration. Table 3 and Table 4 are very helpful to decide the optimal combination of adding/removing machines to the system that minimizes the costs of adding new machines. The reconfiguration layout for each period and each configuration are shown in Fig. 3 until Fig. 6, respectively.

By reflecting from the results above, the company

Table 6 Design of reconfigurable planning results (Configuration 2×6)

Period	Demand (JPH)	Number of machines used		Throughput (JPH)	Reconfiguration cost ($)	Number of existing machines		
		A	B			Baseline	A	B
1	46	4	0	47.08	160,150.70	12	4	0
2	50	5	0	50.02	40,069.22	12	5	0
3	38	1	0	38.25	127.05	12	5	0
4	44	3	0	44.13	83.24	12	5	0
5	37	1	0	38.25	37.68	12	5	0
6	40	2	0	41.20	45.56	12	5	0
7	32	0	0	35.30	59.58	12	5	0
8	33	0	0	35.30	0.00	12	5	0
9	50	5	0	50.02	128.80	12	5	0
10	35	0	0	35.30	148.96	12	5	0
Total reconfiguration cost for periods ($) =					200,820.80			

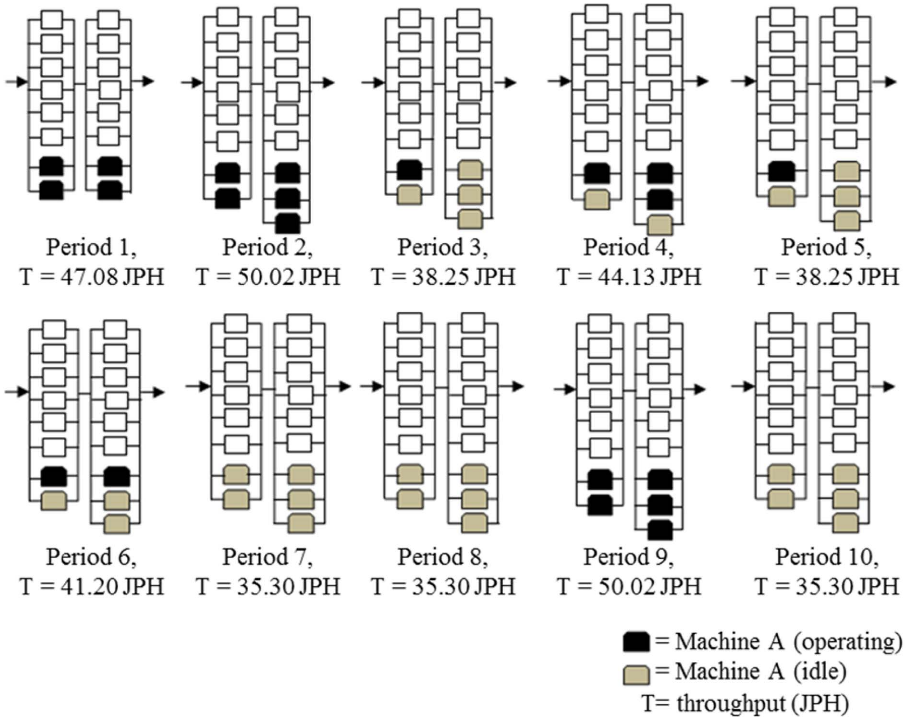


Fig. 3 Design result of reconfiguration layout (Configuration 2×6)

can extract many information related on material handling system, demand forecasting, reconfiguration system, number of reconfigurable machines needed, which can be optimized for future scalability planning to reduce the investment cost. It is also possible to reflect from information derived from the proposed approach, and adjust the decisions based on company's personal strategy. From the calculation above, we can see that configuration 2×6 shows the best reconfiguration planning result, based on the number of new machines added, total reconfiguration cost, and also system throughput. It has the best value of all factors, compared to other configurations. It

Table 7 Design of reconfigurable planning results (Configuration 3×4)

Period	Demand (JPH)	Number of machines used		Throughput (JPH)	Reconfiguration cost ($)	Number of existing machines		
		A	B			Baseline	A	B
1	46	5	0	46.90	200,297.90	12	5	0
2	50	5	1	50.21	50,223.44	12	5	1
3	38	2	0	38.62	186.20	12	5	1
4	44	4	0	44.14	178.75	12	5	1
5	37	2	0	38.62	119.17	12	5	1
6	40	3	0	41.38	119.17	12	5	1
7	32	0	0	33.10	29.79	12	5	1
8	33	0	0	33.10	0.00	12	5	1
9	50	5	1	50.21	372.40	12	5	1
10	35	1	0	35.90	186.20	12	5	1
Total reconfiguration cost for periods ($) =					251,713.00			

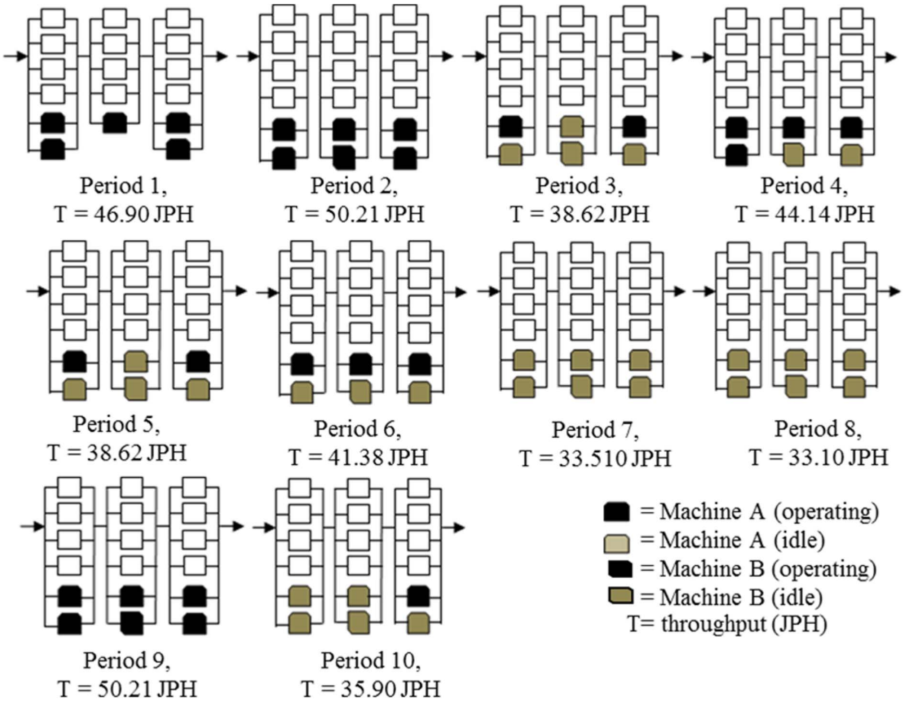


Fig. 4 Design result of reconfiguration layout (Configuration 3×4)

proves that if the minimal capacity increment by which the system output can be adjusted to meet new market demand is small, then the system is highly scalable. Capacity scalability of a manufacturing system is a necessary characteristic for rapidly adjusting the production capacity, allowing the system throughput to be adjusted from one yield to another to meet changing market demand. We define system scalability in percentage, as system scalability = 100 – smallest incremental capacity in percentage.

If the minimal capacity increment by which the system output can be adjusted to meet new market demand is small, then the system is

Table 8 Design of reconfigurable planning results (Configuration 4×3)

Period	Demand (JPH)	Number of machines used		Throughput (JPH)	Reconfiguration cost ($)	Number of existing machines		
		A	B			Baseline	A	B
1	46	6	0	46.36	240,357.50	12	6	0
2	50	4	3	50.48	150,402.20	12	6	3
3	38	3	0	38.63	230.89	12	6	3
4	44	4	1	44.30	223.44	12	6	3
5	37	3	0	38.63	156.41	12	6	3
6	40	4	0	41.21	148.96	12	6	3
7	32	1	0	33.50	119.17	12	6	3
8	33	1	0	33.50	29.79	12	6	3
9	50	4	3	50.48	431.98	12	6	3
10	35	2	0	36.10	230.89	12	6	3
Total reconfiguration cost for periods ($) =					392,331.20			

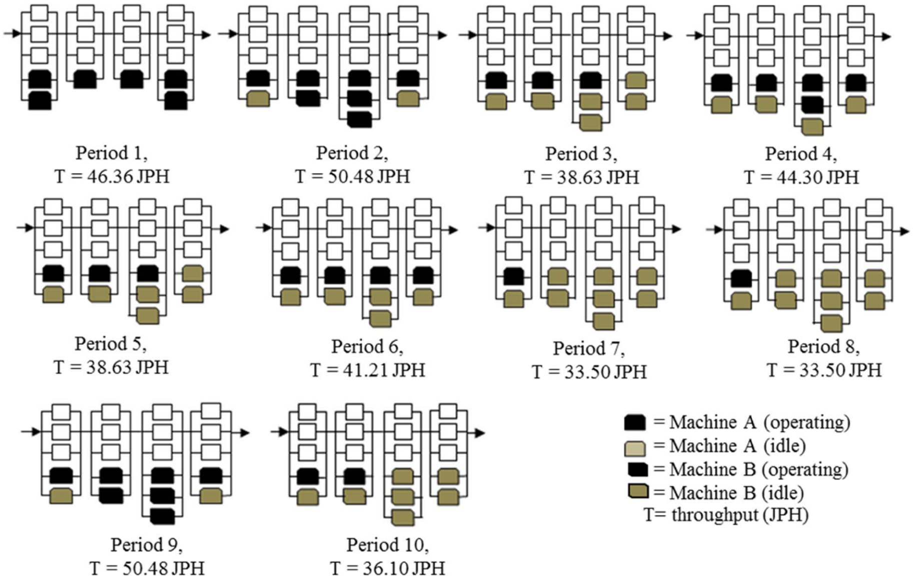


Fig. 5 Design result of reconfiguration layout (Configuration 4×3)

highly scalable. For example, if a serial line (Fig. 7) needs to increase its production capacity to satisfy a larger market demand, an entire new line must be added. Mathematically, the minimum increment of adding production capacity in a serial line is 100% of the system, i.e., adding a whole new line, making the scalability of a serial line 0%. Doubling the line capacity (when double capacity is not really needed) will be expensive because there is no guarantee that the extra capacity will ever be fully utilized, risking thereby a substantial financial loss. Thus, zero scalability means that in order to increase the system capacity, the entire production line must be duplicated. When markets are volatile, designing a manufacturing system with zero scalability is not a good engineering solution. Similar scalability calculations for other configuration systems: configuration 2×6 has scalability of 83.33%, configuration 3×4 has scalability of 75%, configuration 4×3 has scalability of 66.67%, and configuration 6×2 has scalability of 50%.

Table 9 Design of reconfigurable planning results (Configuration 6×2)

Period	Demand (JPH)	Number of machines used		Throughput (JPH)	Reconfiguration cost ($)	Number of existing machines		
		A	B			Baseline	A	B
1	46	3	4	46.04	320,476.70	12	3	4
2	50	6	3	50.23	120,417.10	12	6	4
3	38	2	2	38.14	290.47	12	6	4
4	44	1	5	44.18	50,357.50	12	6	5
5	37	4	0	37.21	394.74	12	6	5
6	40	0	5	40.00	491.57	12	6	5
7	32	2	0	35.60	305.37	12	6	5
8	33	0	2	33.00	208.54	12	6	5
9	50	6	3	50.23	506.46	12	6	5
10	35	2	1	35.35	290.47	12	6	5
Total reconfiguration cost for periods ($) =					493,738.90			

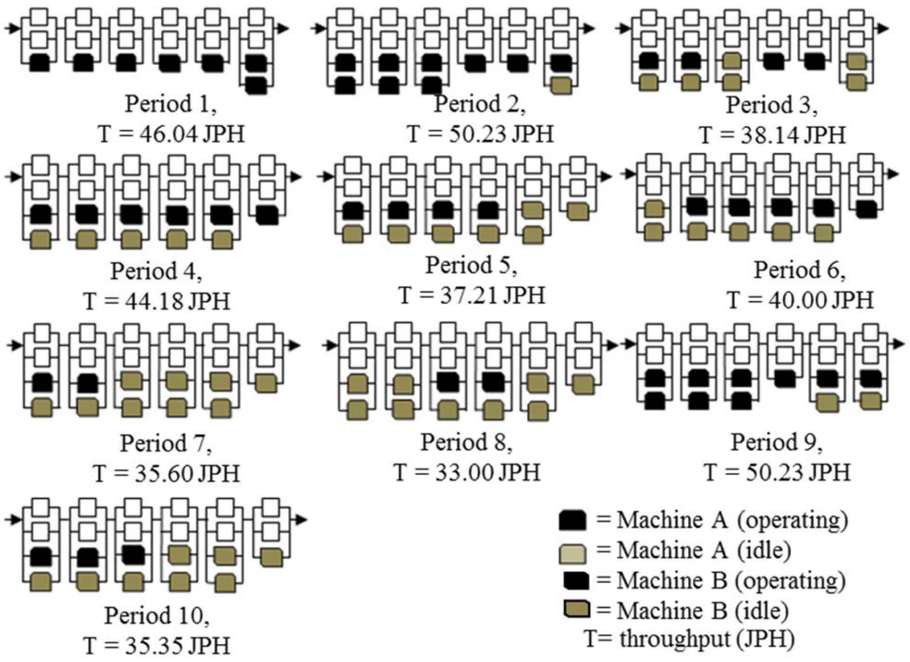
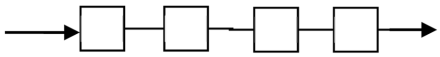


Fig. 6 Design result of reconfiguration layout (Configuration 6×2)



System scalability of assembly line = 100 – smallest incremental capacity in percentage
System scalability of a serial line = 0 %

Fig. 7 Exemplary scalable configurations

5. Conclusions

This current paper elaborates in details on the scalability concept as introduced in Wang and Koren[1]. In comparison, this research presents a systematic approach for developing reconfigurable system design in order to achieve more efficient reconfiguration planning – adding/removing machines for supplying the exact capacity needed to fulfill market demand, as well as minimizing the cost of adding new machines. This research also included more constraints considered and variety of configurations in order to clearly describe the proposed model. Our approach utilizes a reconfiguration planning process that simultaneously changes the system configuration and rebalances the reconfigured system. For the purpose of simplicity, the reference paper[1] only used the total number of machines as the optimization objective. However, in real production, many other cost factors need to be taken in consideration as well. These include labor, tooling, utility, floor space, operating cost, and material handlers[17]. Since a reconfiguration process usually requires shutting down the production system, an extra cost will occur due to the production loss during the reconfiguration process. In addition, our study considers machine utility, reconfiguration processing cost, and machine price.

The proposed approach was validated by using a real industrial case, as explained in Wang and Koren[1]. Experimental results showed that the proposed approach can address the reconfiguration planning problem cost-efficiently and provide methodology for designing configurations. This paper suggests that the proposed study should be performed concurrently with the design of a new manufacturing system. With this approach, the company can extract many information related on material handling system, demand forecasting, reconfiguration system, number of reconfigurable machines needed, which can be optimized for future scalability planning to reduce the investment cost. It is also possible to reflect from information derived from the proposed approach, and adjust the decisions based on company's personal strategy.

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