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Multi objective Sectioning Serial Automatic Disassembly Line Balancing Problem Observance the Disassembly Productivity and Energy Consumption

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Abstract

The To improve the environment and reduce pollution by reducing industrial waste, in addition to protecting workers from the risks of dealing with this industrial waste when they working to treatment the industrial waste, this study will discuss the different scenarios for the disassembly lines. This paper presents a new vision to make decision to change from manual to automatic system by studying new model with case study to confirm feasibility of an application in industrial reality for the purpose of increasing productivity, reducing human effort and manpower consumed in workstations, lessening the quantity of workstations and decreasing cycle time. An automatic disassembly machines in the line need to control in computerized system, thus need to enough power to work with a little human effort. Four scenarios are implemented to verify which is the best application in the industrial reality, and which is more industrially feasible and useful for disassembly line, to balance the problems in the proposed disassembly lines, simulated annealing algorithm improved by chain of Markov with Gibbs sampler and Monte Carlo method, and to obtain global solution from population of solutions, a mufti-objective technique in Pareto optimal solution also verify to confirm optimum solutions.

Keywords: *An automatic disassembly, Improve productivity, Energy consumption, Disassembly machine, Automatic workstations, A multi-objective technique*

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I. INTRODUCTION

The problems Balancing disassembly lines are normally exercised to bring about mass production, recently, computerized numerical control entered the service to a large degree utility in other field, to substitute the monotony manual disassembly and manage the appropriated works should be entered this automatic system in disassembly line, since the technological development and an increasing population in the world today has led to an increase in industrial products to satisfy the needs of people, and these products have a certain life cycle and a short life due to the rapid technological development, an exponential increase of obsolete products has led to an accumulation of these issues which made the matter of disassembly hazard from direct touch part with the people and workers who working in these areas. To avoid diseases from touch the end of life (EOF) products, reducing difficulty of disassembly tasks, and stressful works for workers, it would be necessary to find other methods for disassembly to increase the productivity of disassembly and other objectives, these methods are embodied in the automation of disassembly workstations, that the main objective assignment of any workstation or group of workstations in the disassembly line is to achieve an annual disassembling program for obsolete products. As well as consuming of an energy needed to operate at these workstations to reach optimum productivity per year should be studying to minimize amount as possible as.

This paper proposes improving a productivity requires to a large increasing based on an automation of the workstations with various types of workstation tools, these workstation tools need computerized numerical control(CNC) (see Fig 1(a)) to control for tool movement and obtaining an optimum disassembling processes, workstations by CNC need suitable energy to work every day and twenty four hour per day it is possible to offset the costs of automation operations by making these workstations work two or three shifts per day, and an increasing of their work time at day, we can do these by a high levels of automation by moving disassembly tools in three to five axes and robots arm to pick and places the disassembly products and components after disassembling processes.

Therefore, the energy would be calculated on that time when the workstations perform there functions and carries out the required operations to command for control operations and doing disassembly tasks such as starting motors, moving equipment to remove EOL components from EOL products, in addition to disassembly idle time between tasks, the energy would be increase as well as a continuous working periods of the workstations but this issue can be compensated by huge production of disassembly parts.

This paper also contains the following. In the next section includes the types of disassembly line balancing problem (DLBP) in relating works and precedent articles, also identifying method-related considerations as well as a multi-objective mathematical paradigm for DLBP edited. In third section is describe in particular detail the proposed multi-objectives Pareto ISA algorithm, and how to generate population typically with actual tasks by using proposed meta heuristic algorithm to obtain global solution for disassembly conditions.

In section 4 we demonstrate the new concept technique to obtain professional results and given a mechanical case various scales and a halfway illustration of DLBP to affirm the viability and advantages of the introduced multi-objectives ISA algorithm. In section 5 the obtain results given by verified many times of proposed our algorithms, and compared this results with other previous algorithms.

II. MANUAL AND TRADITIONAL DISASSEMBLY LINES

Assembling parts to make devices became very easy now day, big and small factories at workshops or home work to assembly parts to make many things, this things converts to obsolesce things as results of many factors such as bad made with short reliability for product life lead to make a huge heap of obsolescence devices[1]. although of manual disassembly plans were began to balance this increasing but manual disassembly is not enough to face this rapid obsolete production exact waste of electronic and electric parts. There are many suggestions were studies the disassembly plans to enhance disassembly line works such as [2] was used product self-disassembly technology to increase recovery performance and reduce component damage to improve recovery performance, Aase et al[3]purposed a method to improve labor productivity at assembly line with U shaped, and indicated that the productivity should be enhancement altogether under specific conditions while changing over from a straight line to line looks like U shaped,[4]surveyed the profitability of the cycle time in the U shaped line systems and straight line systems to fix the critical method for the U shaped convergent line for determining hard works in straight lines, on the other hand a meta-heuristic methodology was improved to tackle the issue of adjusting the dismantling line and the issue of adjusting the dismantling line contingent upon the arrangement[5], also improved meta heuristic procedure for balancing a modified U line model with uncertainty disassembly products in another study [6], depending on the completion degree of the auxiliary work for loading and working the workstations system with an automatic and semi-automatic disassembly line [7], a Petri net method was used to predicting energy behavior in flexible processing included automatic systems [8], and a hereditary calculation has been produced for the arrangement the problems of planning a single machine in terms of energy consumption [9], as an apparatus for energy sparing and decrease significant inverse impacts, a few methodologies on planning the energy thought of mechanization lines have been proposed in the study [10], and a method of optimization for energy saving which is selected to choose the workstations on line for picking up and viewing of energy saving by an additional algorithm for the analysis has been developed [11], and a technique for decreasing energy utilization dependent on the limitation relationship chart was proposed and an ant colony evaluation algorithm was improved to find the ideal dismantling progression to choose the sub assembling, disassembly for the recuperation of deliberately significant materials from electric devices was proposed to solve a problems in disassembly lines [12], and [13]suggested a mathematical paradigm to limit power costs for arranging the creation of single machines during creation measures, to reduce energy consumption based on graphical restoration of constraints and improve the algorithm for optimizing ant colony modify was used to find the global collection sequence determined by the selection and the proposed number of components [14], [15] suggested that the problem of balancing the uncertainly disassembly line with the numerous purposes required for the distribution of dismantling tasks for the distributed assembly of dismantling workstations, and to solve the problem of balancing linear collection and the use of Monte Carlo techniques to determine reinforcement training to compile a large-scale problem within a reasonable computational time to solve DLBP [16]), also an artificial swarm algorithm was improved to solve the problems of balancing the linear collection with multi-purpose optimization and optimal Pareto solutions to solve disassembly problem [17], a mathematically multi objective model used to solve parallel line with two products need disassembly [18], two phases heuristic model with mathematical method was proposed again to modify production line [19], and new a strategy was done to create disassembly sequence for tasks item according to be reusing and re manufacturing, a heuristic dependent on multi standards dynamic method has been proposed for task of works to the workstations prepared to disassembly work [20]. Two side disassembly line for big end of life products was proposed by [18] with used improved whale algorithm.

(a) (b)

Figure 1:(a) Proposed automatic disassembly workstation with its various components, (b) Proposed an automatic disassembly line.

III. PROPOSED CHARACTERIZATION

An automatic disassembly line balancing problem need to dividing disassembly line into separate workstations, every workstations contain complete tools to do one or more tasks to verify an objectives of disassembly according to available possibilities (see Fig. 1 (b)), by dividing serial line to small sections that will be lead to improve productivity, reduce idle time and by converting workstation from manual to automatic, the workstation can be work a long time without stops in cycle time and use economic energy to do disassembly because the workstations work with technical plan, to find a better situation we need to study and analyze the solutions and possible technical prospects of the following indicators:

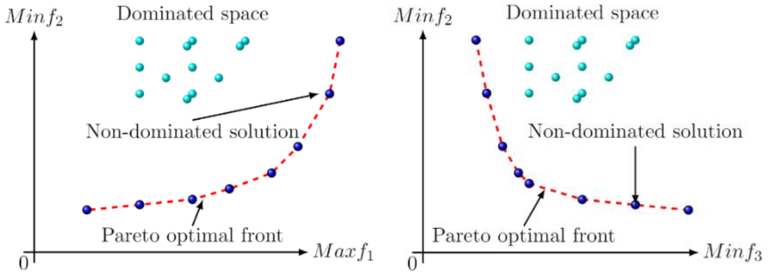
First, probability relies upon the advancement level of science and innovation from the point of view of innovation. Second, in the study and analysis of a series of parameters, such as productivity, quick influence, reliability, work and others, Third, from an economic view, the appropriate possibility to provide the best economic benefits. Fourth, the ideal possibility, cases took all the subsequent design process. The best way to build a disassembly line is based on two basic stages:

First, according to the technical indicators, select the appropriate technical indicators and approve the required disassembly.

Second, according to the economic indicators, choose the most suitable probability in the economy. Energy level distribution of workstations represented by the proportion of workstations assigned to the total size of the demolition, the minimum number of workstations is greater than zero.

To verify and test SSADLBP, we have chosen a real mechanical devices, It is widely used in subways and locomotives, the mechanical sensing valve are presented in Table 1.

ISAA embedding with MCMC obtain to select a suitable solutions from proposed population and prefer to choose a global solutions to obtain optimum workstation assignment, the productivity and energy consumption are two opposites objectives (see Fig. 3), and other two objectives (f3 and f4) are the same condition objectives (min-min) as shown in Fig. 3, however the power of workstations for the disassembly line is a necessary to optimize a problem with complex constraints to obtain a global solution in a case of complete disassembly of the EOL products, and to improve productivity of disassembly is depending on the energy of the disassembly work distribution because the number of workstations need enough power to do functions, the productivity of the workstation and the mechanical energy required for remove components from EOL components.



(a) (b)

Figure 2 Pareto-optimal front containing multi objectives problem and the solution area combination between max and min in (a), and the solution area combination between minimum objectives in (b)

IV. Definition of the problem and model

The innovation of this paper is to divide the serial disassembly line into multiple sections, and the advantages of the proposed model have been demonstrated by analyzing four scenarios cases and the difference between one department and a conventional workstation As is known, the traditional workstation also contains only a worker (human or robot) such as One section, but the real difference lies in the investment and operating costs of each of the two types. In the manual disassembly line, it is true that the instantaneous operating costs are low, but the long-term investment costs a very high amount while the opposite is true in the case of the automatic disassembly line. We discussed this difference in this paper.

V. NOTATION

f_1	**Increase productivity**
f_2	**Minimize energy consumption**
f_3	**Minimize idle time**
f_4	**Minimize quantity of workstations**
ω_p	**The quantity of parallel lines**
δ	**An average coefficient of inter sectional imposition of productivity losses**
n_s	**quantity of sections at workstation**
φ	**Growth of workstations productivity**
k_{tec}	**A parameter describing the degree of technical processing of the disassembly line**
N_y	**Investment per years**
δ_φ	**A variation of disassembly investment for one product**
E_i	**Input energy for disassembly operations**
E_{le}	**An energy losses for disassembly operations**
E_{lm}	**An energy friction loss of mechanical transmission system**
E_{dis}	**An energy for disassembly**
E_{idle}	**An energy used at idle time**
E_{loss1}	**An energy losses**
t_c	**Cycle time**
$t_{o.t}$	**Lost time outside the disassembly cycle time due to technical reasons**
t_n	**An optional period of time to study the functionality of the disassembling equipment**
θ_n	**The average time required to reset and calibrate the disassembling equipment**
θ_p	**The total time required for disassembling equipment to perform its functions**
u	**Random variable an independent**
ϵ	**A decreasing ratio of energy cost**
$E_{\mathrm{tc}_{\mathrm{ij}}}$	**The energy consumption to change tool**
$P_{\mathrm{tc}_{\mathrm{i}}}$	**The power need to change tools**
Qty	**The quantity of disassembly parts.**
T	**The tool which is using to remove part**
D	**The direction of disassembly part when removing in disassembly process**
p	**The preceding disassembly part**
t	**The disassembly time unit to remove part**

VI. Creating population

To build up the population for the disassembly line based to SSADLBP by using improved simulating annealing algorithm (ISAA) and MCMC to balance solution to evaluate of prior, likelihood, and posterior distributions for disassembly solutions, this population would be typically suitable for solving discrete and continue optimization problems, and the decoding method is discredited as shown in instant example contains 9 parts Fig. 2(a), and the technique which is used to determine the sequence of disassembly parts in the line Fig. 2(b), this example needs disassembling under four objectives with limit constraints such as sequence in workstations and other constrains in equations (23-34), and flowchart in Fig. 7, to obtain an initial population for the allocation of the workstations and the assignment of works should be determined in the flowing:

Step 1: select the current assignment in order of disassembly sequence from left to right, if the work is not completed, perform step 2; otherwise, step 5.

Step 2: calculate the actual disassembly time for the current assignment, including job time, adjustment time, and sequential correlation time. The calculation of adjustment time is based on the disassembly direction of each adjacent work in the disassembly sequence, and determines whether each work needs to adjust the operation, if the disassembly direction of a work is inconsistent with that of the previous work, the determination of the sequence priority should be combined with the disassembly sequence and the sequence priority matrix, and for the two disassembly works with sequence correlation, determine the location of each work in the disassembly sequence a work has an impact on the execution of another work.

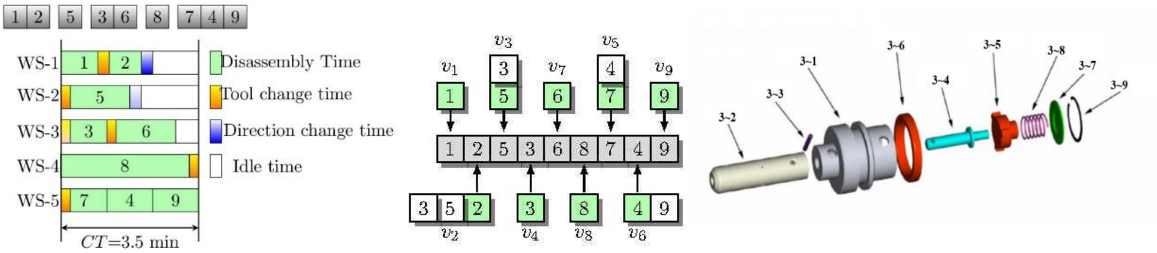


Figure 3 A schematic diagram of disassembly priority of removing 9 parts under consideration by using proposed steps to obtain the objectives.

Step 3: determine whether the actual disassembly time of the current assignment work is not exactly the leftover disperse time of the momentum workstation, provided that this is true, appoint the work to the current workstation, and the excess disseminate time of the workstation will be reduced. Perform step 1; otherwise, step 4.

Step 4: open a new workstation, reset the remaining allowable time to idle time, and perform step 3.

Step 5: output the a location of every tasks in the disassembly sequence, and assigned workstations, the workstation time and whether or not to perform the adjustment operation according to four objectives, and the decoding program go ahead to ends.

suppose N components need removing sequence, each component is defined as a disassembly work, according to the physical constraints between the components, the priority relation diagram of the components is drawn and the disassembly priority relation matrix is determined.

$$A_{m\times n} = \begin{array}{c} \\ c_{i=1} \\ c_{i=2} \\ \vdots \\ c_{i=n} \end{array} \begin{array}{c} \begin{array}{cccc} c_{j=1} & c_{j=2} & \cdots & c_{j=n} \end{array} \\ \begin{pmatrix} b_{1,1} & b_{1,2} & \cdots & b_{1,n} \\ b_{2,1} & b_{2,2} & \cdots & b_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{m,1} & b_{m,2} & \cdots & b_{m,n} \end{pmatrix} \end{array}$$

Where $A_{m\times n}$ disassembly priority matrix ; c_i,c_j components numbered i, j; n is a overall components; b_{ij} is disassembly preference of components c_i and components c_j,if component c_i takes precedence over component c_j, $b_{ij} = 1$,otherwise c_j,$b_{ij} = 0$.

The quantity of the initial population in the improved simulating annealing algorithm(ISAA) have a certain effect on the convergence treatment and execution of the algorithm, in order to expand the search scope a group of one dimensional arrays with n length is randomly generated on the basis of satisfying the constraint of priority relation, the n times are repeated and the initial population of n is generated, among of them satisfying the constraint of priority relation ensures that the random solution is in the feasible region besides the difference between these random solutions and a global search, steps for constructing a random solution are as follows:

Step 1: according to the priority relation diagram, algorithm establishes the priority relation matrix, initialize the disassembly sequence position K_1.
Step 2: find out the work j that makes it work and add it to the candidate work V_k (see Fig.4).
Step 3: determine whether the candidate work set holds, if so, perform step 6; otherwise, perform step 4.
Step 4: randomly select a work J_1 in V_K to relegate to the K situation of the disassembly succession.
Step 5: rebuild the precedence matrix, constrain the assigned work j_1, so that the work j_1 will not be a candidate again, and the work j_1 allocation does not impose constraints on other works. Therefore, release the constraints on the unassigned works from the assigned work J_1, make K_1, K_1, and perform step 2.
Step 6: output the disassembly sequence, and the random solution constructor ends.

VII.MODELING OF MULTI OBJECTIVES TO BALANCE DISASSEMBLY LINE

MODEL OF PRODUCTIVITY

According to the method based on multi objectives containing four objectives, a main objective Q_{max} aim to maximize the productivity of the automated disassembly line (AMPDL), to obtain this objective Q_{max} based to SSADLBP relating to this following equation:

$$\text{maximize} f_1 = \sum_{w=1}^{w} Q \qquad (1)$$

The automated disassembly line productivity Q (part/min) (Usubamatov, R.et al., 2013). and (Oshurkov, V. Aet al., 2016). with Limited buffer capacity, the maximum productivity must be related the maximum buffer, and the location of the buffer near the workstation is
considered in the serial line (Shi and Men (2003)) and, (Sabuncuoglu et al., (2014)) refer to relationship between productivity and capacity of buffer, thus the main objective here is considering this relationship and other (see Fig. 5, and Fig. 6).

$$Q = \frac{w_p}{\frac{T_d}{w_q} + T_a + \frac{w_p w_q \sum T_i}{n}\left[1 + \frac{2\delta(1-\delta^{n-1})}{1-\delta}\right]} \qquad (2)$$

Where w_p refer to workstation in parallel line, here $w_p = 1$; T_d components disassembly in cycle time; T_a adjusting time (component/min); T_i idle time loss at single workstation (min/component); w_q is the quantity of sequential workstations in SSADLBP.
The relationship between productivity Q_c and quantity of workstations W is shown in the equation (3) with a special cases,where productivity increases at the beginning with the increase in the quantity of workstations and after that it decreases sharply, there is an ideal value for the quantity of workstations W, which achieve the greatest productivity Q_{max} ,this ideal value can be obtained by taking the first derivative and equating it with zero in equation (4)

$$Q_c = f(W) \qquad (3)$$

.

$$\frac{dQ_w}{dw} = 0 \; (4)$$

in the event of an unequal distribution of the works in workstations and having regular breakdowns and stops, productivity will always be less than theoretical value Q_w in equation (5).

$$Q_w = \frac{1}{\frac{t_{po}}{W} + t_{x.x} + \sum ci + W t_c} \qquad (5)$$

Where t_{po} is a time of removal parts, $t_{x.x}$ is time of non removal parts, $\sum c_i$ total of losses outside of disassembly tools, and t_c is losses of outside disassembly tools for one mechanism on the disassembly line.

MODEL OF DISASSEMBLY ENERGY ENGERGY CONSUMPION OF WORKSTATIONS ENERGY CONSUMPTION ANALYSIS

The second objective assignment refer to minimize the consumption of the energy would be used in the disassembly workstation, this objective aim to minimizing the power as long as the automatic workstation are working, and the model can be model as following:

$$\text{minimize} f_2 = \sum_{w=1}^{w} EC(s) \qquad (6)$$

Workstations and other equipment would be attaching in disassembly line need enough energy to work, these energy can be determine in following:

MODEL OF START UP

In the stand by periods, the disassembly machines getting ready to do the work, so that the value of the removing energy E_{dis} is zero; when the remover arm rise from a starting to the require force, the energy of the step motors or servo motors to obtain the consumption energy uses for the moving parts to remove disassembly components, a kinematic energy changes sternly. Therefore, the EC model as follows:

$$E_i(t) = E_{le}(t) + E_{lm}(t) + dE_m/dt + dE_k/dt \qquad (7)$$

Ei is the input energy. E_{le} is the energy losses ; E_{lm} is the loss energy of shifting parts; Em is the energy consumption of motor's magnetic field. E_k is the consumption energy of the mechanical system .

ENERGY CONSUMPTION MODEL FOR IDLE TIME

In an idle time, a disassembly EC E_{dis}, and the work done by the disassembly machines is constant,so the energy of the stepper motors (magnetic field) ,and the utilization energy of the movable parts are almost consistent. Accordingly, the energy utilization of the idle time is as per the following:

$$E_{idle}(n) = E_{loss\,1}(n) + E_{loss\,2}(n) \quad (8)$$

E_{idle} an energy in an idle time i_{th} of workstation, $E_{loss\,1}$ is the energy loss of i_{th} workstation, and $E_{loss\,2}$ is the loss energy of the mechanical transmission system in the main driving system

DISASSEMBLY ENERGY CONSUMPTION

In the disassembling periods, E_{dis} the mechanical transmission system of the workstation, the consumption energy of the moving tool arm is change heavily, and the amount of dEm/dt and dEk/dt are approximately equal to 0. Therefore, a consumption of the disassembling energy time is as follows:

$$E_i(t) = E_{le}(t) + E_{lm}(t) + E_{dis}(t) \quad (9)$$

ENERGY CONSUMPTION OF DISASSEMBLY TOOL CHANGING

As evidenced by the disassembly technique of adjacent disassembly works arrangement, it may be important to change a tool, normal tool change time can be obtained by using fact strategy. Energy usage to change tool can be planned as follows:

$$E_{tc_{ij}} = P_{tc_i} \cdot \left(t_{std} + \delta pos_j \cdot t_{tc0}\right) \quad (10)$$

where P_{tc_i} is power of the tool change at the i_{th} workstation, t_{std} is the steady time of working tool, δpos_j is the moved number of the tool from the $(k-1)$th part to that of the k-th part, and t_{tc0} is a time of the tool holder.

MODEL OF WORKSTATIONS

The third objective assignment is determine to minimize the workstations, in actual terms as work for the limitation quantity of workstations

$$\text{Minimize}f_3 = \sum_{k=1}^{k} W_{optimum}\ . \quad (11)$$

$$W_{min} \le W_{optimum} \le W_{max} \quad (12)$$

$$W_{optimum} = \sqrt{\frac{t_{po}}{t_c}} = \sqrt{\frac{t_{po}}{\omega_c \tau_B}} \quad (13)$$

$$W_{max} = \mu\sqrt{\frac{\alpha}{\beta}} \quad (14)$$

$$\mu = \sqrt{\frac{K_{tec} + Nm}{K_{tec} + N(m + \frac{1}{\epsilon})}} \quad (15)$$

The quantity of sections at disassembly line can be obtain by the relationship:

$$n_s = \frac{W_{Tex}}{W_{max}} \quad (16)$$

Where W_{Tex} is quantity of workstations in disassembly line related to technical plan

MODEL OF IDLING TIME

Total losses time is one of the most important factors affecting productivity and work ability of the workstation. In this objective is assign to minimum of total idling time of all workstations, taking into consideration balance of workstations:

$$\min f_4 = \sum_{k=1}^{k} (W_k . t_c - t_k)^2 . \quad (17)$$

The total idle time can be calculate :

$$\sum t_k = \sum t_c + \sum t_{o.t} + \sum t_n \quad (18)$$

Total losses time is one of the most important factors affecting in productivity and work ability of the workstation, and this time is calculated by equation (19)

$$\sum t_k = \frac{\sum \theta_n}{z} = \frac{\theta_n}{\theta_p} . T \quad (19)$$

and Similarly we can calculate another losses times by equations (20),(21),(22) respectively.

$$\sum t_c = \frac{\sum \theta_c}{\theta_p} . T \quad (20)$$

$$\sum t_{o.T} = \frac{\sum \theta_{o.T}}{\theta_p} . T \quad (21)$$

$$\sum t_n = \frac{\sum \theta_n}{\theta_p} . T \quad (22)$$

CONSTRAINS:

Equations(23-26) ensures that all parts are disassembled and each disassembly work is located in different positions in the disassembly sequence.

$$\sum_{i=1}^{n}\sum_{k=1}^{n} w_{ik} = \frac{(n-1).n}{2} \tag{23}$$

$$w_{ik} = 0, \forall i \tag{24}$$

$$w_{ik} + w_{ki} = 1, \forall i, \forall k, i \neq k \tag{25}$$

$$\sum_{j=1}^{n} w_{ik} \neq \sum_{k=1}^{n} w_{i'k}, \forall i, \neq i', i \neq i' \tag{26}$$

Equation (27) for the precedence constraint of the disassembly sequence, the position of a work in the disassembly sequence is less than the position of the work before the disassembly sequence have been completed.

$$\sum_{k=1}^{n} w_{ik} > \sum_{k=1}^{n} w_{uk}, \forall i, \forall u \in \{u|a_{ui} = 1\} \tag{27}$$

$$p_i = \sum_{k=1}^{n} w_{ik} + 1, \forall i \tag{28}$$

$$T_j = \sum_{k=1}^{n} ((t_k + \sum_{k=1}^{n} (s_{ik} \times w_{ik} + t_s \times z_k) \times v_{jk}), \forall j) \tag{29}$$

$$T_j \leq T_c, \forall j \tag{30}$$

$$\sum_{j=1}^{j} v_{ij} = 1, \forall i \tag{31}$$

$$v_{ij} \leq \sum_{e=1}^{j} v_{1e}, \forall j, \forall i, \forall l \in \{v|p_l < p_i\} \tag{32}$$

$$z_j = 1, \forall j \in \{j|p_j \neq 1, r_j \neq r_v, v \in \{v|p_v = p_j - 1\}\} \tag{33}$$

$$v_{ik}, w_{ij}, z_j, S_k \in \{0,0\} \forall i, \forall j, \forall k \tag{34}$$

Equation (28) determines the position of every work in the disassembly Progress. Equation (29) determine the working time of every workstation, including the work time of disassembling work. Equation (30) is a losses time constraint, indicating that working time doesn't surpass the idle time. Equation (31) is a work allocation constraint to ensure that all works are allocated, furthermore, every disassembly work must be relegated to a workstation. Equation (32) is the priority relationship constraint of work allocation, which indicates that the pre task in the disassembly sequence is assigned to the workstation first. Equation (33) determine whether the disassembly work is adjusted or not, only if the work is adjusted. The latter work needs to perform the adjustment operation before the disassembly operation begins and change the placement position of the EOL. Equation (34) defines the 0-1 variables of $v_{ik}, w_{ij}, Z_j,$ andW_k.

VIII. ALGORITHM STRUCTURE AND CASE STUDY

ALGORITHM STRUCTURE

The proposed algorithm obtains to find global solution in the area containing several non-bad solutions, this area for pareto optimal frontier was estimated by using the offspring distance (OD) equation (35) to test the stability of the proposed ISAA.

$$OD = \sqrt{\frac{1}{n_{PF}} \sum_{i=1}^{n_{PF}} d_i^2} \tag{35}$$

OD offspring distance, n_{PF} not subordinate sets in the current set of optimal Pareto solutions obtained using the running algorithm, d_i^2 distance of the global solution in the set of the $i-th$ is non bad solution, to increase of labor productivity constitutes the main criterion to choose the optimal structural possibility for the production line, which allows to calculate the increase in the productivity of the line, change the total costs and investment expenses, by reducing the quantity of workers on the line and the work period. In order to correctly determine the quantity of sectors, it is necessary to perform a comparison of the parameters of automated line and manual line consisting of the same workstations. It is possible to obtain sufficient accuracy during the calculation taking into account the following assumptions:

1. The workstations in the automated line are the same, the loss times on all workstations are equal.
2. The storage and feeding operations between the processes in the manual line allow to avoid the mutual relationship between the workstations, while in the automated line with the rigid line, the failure of any work station leads to the suspension of the rest of the work stations.
3. The costs on automation line are not related to the quantity of workstations. The rate of work productivity λ increase in the flow line compared to the automated line is determined by an equation (36)

$$\lambda = \frac{Q_2}{Q_1} = \epsilon\varphi \frac{K_{tec} + N_y(m_c + 1)}{k_{tec}\,\sigma + N_y\left(m_c \delta_\varphi + \frac{1}{\varepsilon}\right)} \tag{36}$$

Where Q_1 work productivity achieved by equipment and technology of the first type, and Q_2 work productivity achieved by equipment and technology of the second type, φ growth of workstations productivity,k_{tec} is a parameter describing the degree of technical processing of the disassembly line ,N_y investment period by years, σ is the variation of disassembly tools cost ,ϵ is decreasing ratio of energy cost,δ_φ is is the variation of disassembly energy for one product,m_c is energy cost factor.

The multi objective improved simulated annealing algorithm is improved by joining to MCMC to develop searching in solutions area, and to compute the present propose method SSDLPB, and implementation process of ISAA, and can be summarize in the following detail:

Step 1: set algorithm parameters, population size N, maximum epoch number $\mathrm{Max}_{\mathrm{gen}}$, probability Pa.

Step 2: process of constructing a random solution according to generates an initialized population with a scale of N .

Step 3: process of initialize the algorithm epoch counter $\mathrm{epoch} = 1$.

Step 4: calculate the objectives assignment $f_1, f_2, f_3, \mathrm{and} f_4$ of the individual in the population, select the non-bad set by using the definition of the pareto optimal solution set.

Step 5: keep the non-bad set in the external file and update the bad solution according to ISAA operation.

Step 6: generate random probability P to simulate the discovery probability of ISAA, determine whether the random probability P is greater than Pa, if it is established, carry out local search and update the neighbor location according to the operation of ISAA; otherwise, directly execute step 7.

Step 7: calculate the objective assignment valuef_1, f_2, f_3, and f_4, filter the non bad set, and update D in the external file.

Step 8: compute total non-bad sets of N_D: if $N_D > N_0$, create MCMC population of non-bad sets according to the formula, keep N_0 not the worst solutions with large total overcrowded distance in D, otherwise perform step 9 directly.

Step 9: update the population: recalculate the number of non-subordinate sets of data files, calculate the total clustering distance of not the worst sets, choose N which is not the worst solution in the larger total cluster distance as a new population; otherwise, according to the random solution construction process.

Step 10: taking a decision whether the algorithm epoch counter epoch reaches the maximum number of epochs $\mathrm{Max}_{\mathrm{gen}}$, and if it is reaches epoch is established, let $\mathrm{epoch} = \mathrm{epoch} + 1$ and go to step 4; otherwise, outputting the non-bad solution in the external data file to obtain an optimal disassembly scheme, and the algorithm is terminated.

MARKOV CHAIN AND GIBBS SAMPLING

Markov chain Monte Carlo (MCMC) is a procedure for assessing by reproduction the desire for a measurement in an intricate model (Montazemi et al., (2015)., Chatterjee, S. et al., (2008)., Levy, R. et al., (2011).). MCMC was used in this paper to draw tests where the accompanying model is dependent on the present model, and this allows the computations to restrain in on the sum that is being approximated from the allotment, even with a random variables for large number, we attached MCMC to ISAA to obtain optimal solutions, as shown in Fig. 8, one of the particular strengths of the MonteCarlo (Gibbs sampler) approach in markov chain is the ability to make inferences about random functions of unknown model parameters, we might compute the disassembly Probability Rank for each disassembling plan in each epoch in prior, likelihood, and posterior distributions. MCMC operation is an intermittent and irregular global search mode, which has advantages in searching of the local optimal solution and expanding the search range.

The distribution of prior distribution of θ represents possible parameter values, from which the parameterθ has been drawn.

CASE STUDY

To investigate this proposed algorithm ISAA, an example case study as shown in Fig. 5 has been chosen to investigate ISAA in propose SSADLBP, a sensing valve is important device in Railway Truck and Vehicle, it is senses in braking, retardation, retaining, and stopping, and apply with mechanical system to brake Truck and Vehicle, and due to this importance, it is regularly replaced with a new one to avoid accident, and the first one becomes damaged and needs to be disassembly, also parts deception and disassembly characteristics as shown in Table 1, and another small case study as represent by Small end of life electronic and electrical products, which contained very small electronic components, which is very difficult to disassemble by hand as shown in Fig.5.

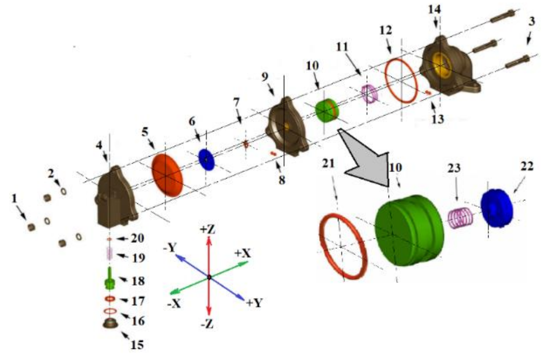
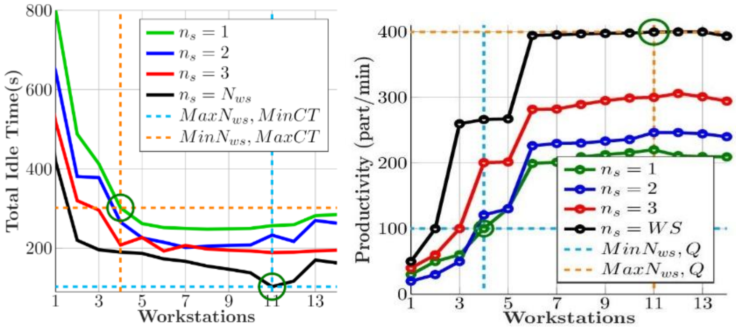


Figure 5 Another example is mechanical sensing valve needs to disassemble processes contains 23 parts.



(a) (b)

Figure 6 (a)A range of idle time via number of workstations, (b) range of productivity per min via number of workstations NWS

Table 1: Disassembly characteristics of the mechanical sensing valve

No	Name	Qty	D	T	P	t
1.	Nut	3	-1	T1	-	3
2.	washer	3	-1	T2	1	0.69
3.	Bolt	3	+1	T3	2	1
4.	Cap	1	-1	T2	2	0.9
5.	Plate	1	-1	T4	-	0.30
6.	rod	1	-1	T5	5	1.9
7.	seal	1	-1	T6	9	0.6
8.	gasket	2	-1	T7	9, 14	0.89
9.	Int. body	1	-1	T4	5, 18	0.7
10.	Valve body	1	+1	T4	5	1.5
11.	Spring	1	-1	T2	13, 14,15	0.7
12.	O seal	1	-1	T7	9,14	0.6
13.	gasket	2	-1	T7	14	0.5
14.	Back body	1	+1	T5	9	0.5
15.	Back cover	1	-3	T8	11,18,20	0.7
16.	O seal	1	-3	T7	15,20	1.7
17.	Y seal	1	-3	T7	18,22	3
18.	piston	1	-3	T6	15,19	1
19.	spring	1	+3	T2	9,15,18	1.4
20.	Screw	1	+3	T2	14	1.4
21.	O seal	1	+1	T2	10	0.5
22.	gland	1	-1	T7	10	0.8
23.	valve spring	1	+1	T2	10,22	1.3

IX. RESULTS

COMPUTATIONAL RESULTS

ALL above mathematical models were implemented in PC with Microsoft windows 10, the PC is prepared by Intel Core (R) and (TM) i710510 CPU 2.30 GHZ and 16 GB RAM, the propose algorithm is coded and verified in matlab R2016a, and python 3 in anaconda navigator platform. Computational results extracted from data related with four scenarios ($n_s = 1,2,3,6$) to compare between them and determine the best scenario, the four scenarios is considered comprehensive probability may be applied in industrial realities, and here we present summarize of these scenarios:

FIRST SCENARIO

To balance disassembly line we supposed in this scenario all disassembly machines in one section $n_s = 1$, and investigate the system according to pareto multi-objective, the model gives 12 solutions for four objectives, these results for disassembling sensing valve containing 23 parts, the tasks are sequence and determine at 6 workstations and one section as shown in Fig. 14(a)

SECOND SCENARIO

To balance disassembly line in second scenario the disassembly machines can be dividing in two sections $n_s = 2$, each section is considered semi separating from other sections. The results as shown in Table 2, the tasks are sequence and determine at 6 workstations and two sections as shown in Fig. 14(b).

THIRD SCENARIO

To balance disassembly line in third scenario the disassembly machines can be dividing in three sections $n_s = 3$. The results as shown in Table 3, the tasks are sequence and determine at 6 workstations and two sections as shown in Fig. 14(c).

FOURTH SCENARIO

This scenario the disassembly machines can be dividing in six sections $n_s = 6$. The results as shown in Table 4, the tasks are sequence and determine at 6 workstations and two sections as shown in Fig. 14(d).

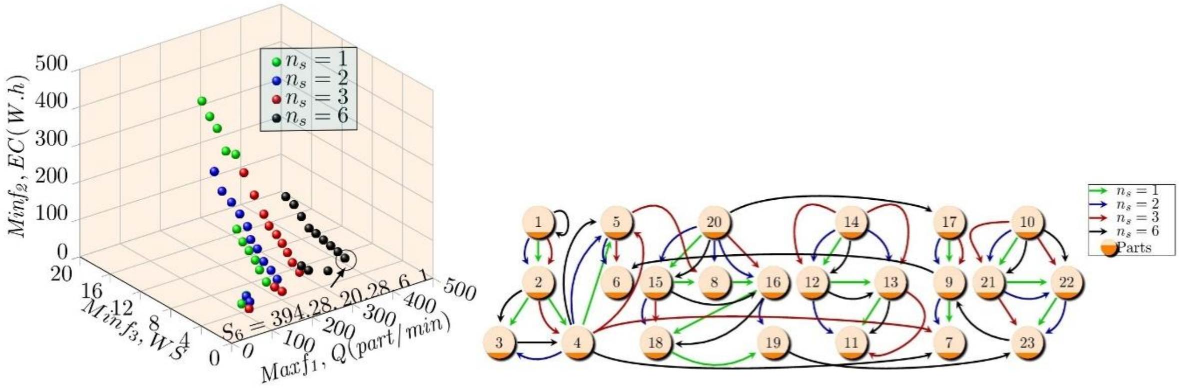


Figure 7: The optimal Pareto solutions of the SDLBP for 4 scenarios compared by ISAA, and observed by MCMC, S6 refer to global solution.

SUMMARY OF SCENARIOS

The study in four scenarios proved that, while more sectors of workstations in the disassembly line increased, the more productivity and less energy consumed, when aggregate productivity and energy measured, propose ISAA gives a various results as shown in Fig. 6(a), and the cycle time dramatically decreased when we convert from one section to six sections at disassembly line.

Table 2: The Pareto frontier of the four alternatives values of the goals f_1, f_2, f_3 and f_4 via second scenario ($n_s = 2$) indicating the superior performance.

No	f_1	f_2	f_3	f_4
1	239.8	201.4	15	3.1
2	240.1	160.3	14	4.1
3	244.5	140.6	13	4.3
4	246.4	120.3	12	5.0
5	246.5	98.4	11	5.1
6	235.8	78.8	10	5.3
7	233.4	66.5	9	5.5
8	230.3	45.3	8	5.7
9	229.8	33.6	7	5.9
10	226.3	22.1	6	6.2
11	130.3	22.1	5	7.6
12	120.8	22.1	4	9.1
Max	246.5	201.4	15	3.1
Min	120.8	22.1	4	3.1

Table 3: The Pareto frontier of the four alternatives values of the goals f_1, f_2, f_3 and f_4 via second scenario ($n_s = 3$) indicating the superior performance.

No	f_1	f_2	f_3	f_4
1	294.3	190.9	14	1.90
2	301.2	140.3	13	1.95
3	306.2	99.12	12	1.90

4	**300.1**	**81.44**	**11**	**1.89**
5	**299.7**	**70.21**	**10**	**1.93**
6	**295.0**	**59.76**	**9**	**1,95**
7	**289.2**	**48.76**	**8**	**1.98**
8	**282.7**	**35.65**	**7**	**2.07**
9	**281.6**	**22.34**	**6**	**2.3**
10	**201.3**	**22.11**	**5**	**2.27**
11	**200.6**	**22.10**	**4**	**2.08**
12	**100.1**	**22.00**	**3**	**3.02**
Max	**306.2**	**190.9**	**14**	**2.27**
Min	**100.1**	**22.00**	**3**	**1.89**

Table 4: The Pareto frontier of the four alternatives values of the goals f_1 , f_2 , f_3 and f_4 via second scenario ($n_s = N_{ws}$) indicating the superior performance.

No	f_1	f_2	f_3	f_4
1	**398.33**	**90.77**	**14**	**0.4**
2	**399.75**	**80.6**	**13**	**0.5**
3	**399.25**	**60.55**	**12**	**0.6**
4	**399.54**	**40.50**	**11**	**0.8**
5	**398.00**	**38.56**	**10**	**0.9**
6	**397.44**	**33.33**	**9**	**1.0**
7	**396.75**	**29.50**	**8**	**1.1**
8	**395.25**	**25.65**	**7**	**1.2**
9	**394.28**	**20.28**	**6**	**1.3**
10	**267.32**	**55.33**	**5**	**1.8**
11	**266.25**	**55.32**	**4**	**1.9**
12	**295.75**	**55.30**	**3**	**1.9**
Max	**399.75**	**90.77**	**14**	**1.9**
Min	**266.25**	**20.28**	**3**	**0.4**

X. DISCUSSION

Initiating the productivity and energy prediction of the intervals or the aggregate production and power consumption forecast model of four scenarios in disassembly line balancing problem, measuring the productivity and energy consumption of processing and idling time to obtain the function of the appropriated curve of productivity and energy consumption, to calculate power consumption in the automatic disassembly we estimated that an every workstation need enough power to work, this power determine by estimating the maximum energy enough to remove part from waste product, according to mathematical model in an aggregate energy estimated and observed in 6 workstations, total energy in four scenarios as shown in chart Fig. 6(a) indicate to scenario number four is least energy at workstation, there is also an amount of energy consumed during the automatic tool changing, when the number of operating sectors increases, the energy consumed decreases because the tool change time decreases with the increase in sectors at disassembly, see the diagram Fig. 6(b). The productivity was high level at $n_s = 6$, it has risen from $149.7 part/min$ when $n_s = 1$ to $687.2 part/min$ when $n_s = 6$, and in Fig. 6(a) has shown a dramatically increasing productivity between $minN_{ws} = 3$,and $maxN_{ws} = 11$, and in Fig. 9 the energy consumption go down from $54.99 W.h$ when $n_s = 1$ to $28.64 W.h$ when $n_s = 4$, the study determined the optimum number of workstations $minN_{ws}$=4, and the max number of workstations $maxN_{ws} = 11$. As seen from Fig. 12, the Investigation of the $n_s = N_{ws}$ is more excellent to that of the $n_s = 1$ on the whole, and it can be seen from Fig. 7 that an normal values of the four objectives f_1, f_2, f_3, and f_4 at $n_s = N_{ws}$ more than the objectives associated with $n_s = 3$, $n_s = 2$, or $n_s = 1$. and lists the corresponding work order scheduler every not the worst ISAA solution According to Fig. 14(d), number of workstations, and idle time were minimal for $n_s = N_{ws}$. production increased to more than four times at $n_s = N_{ws}$, 52.08% energy saving in a disassembly processes when dividing disassembly line to six, sections $n_s = N_{ws}$ (see Fig. 9) ,and 40.80% when dividing to three sections $n_s = 3$. Fig. 10 show that energy consumption is dramatically decreased as N_{ws} is increasing. However, the productivity increases significantly. Fig. 16 shows computing the productivity and energy consumption when cycle time was taken at the optimal disassembly of idling time, disassembling processes, and tool change of every workstation in solutions $n_s = 1$. As shown in Fig. 14(a), the cycle time is considered high compared to other sections $CT = 6.921 min$, total productivity and workstation power consumption may not decrease when standby power consumption decreases Fig. 14(b) shows in double section ($n_s = 2$), the reduction of cycle time rather than $n_s = 1$, when $CT = 6.1 min$, clearly we can see wide range productivity where $n_s = N_{ws}$, mean and median tend to max productivity $Q = 400 part/min$, and low energy consumption, and idling time with tight range of population, table 6 show the optimum solutions for distribute tasks in workstations to obtain the optimum four objectives.

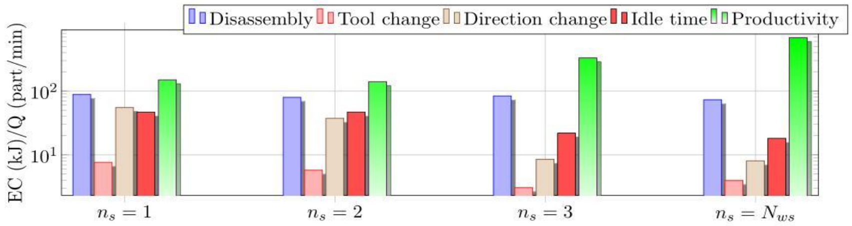


Figure 9 Aggregate productivity and energy consumption observed in ns=1,2,3, and 6, deduced and measured by ISAA in SSADLBP.

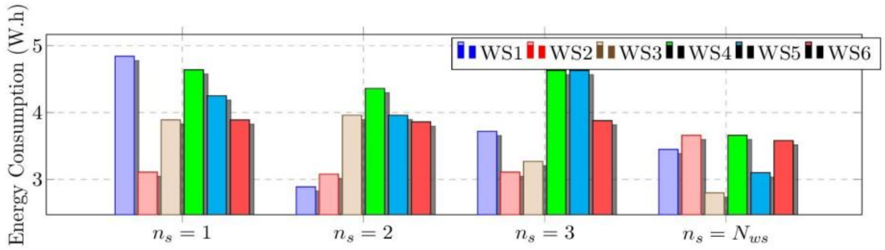


Figure 10 Energy consumption during disassembling processes observed in ns=1,2,3, and 6, deduced and measured by ISAA in SSADLBP.

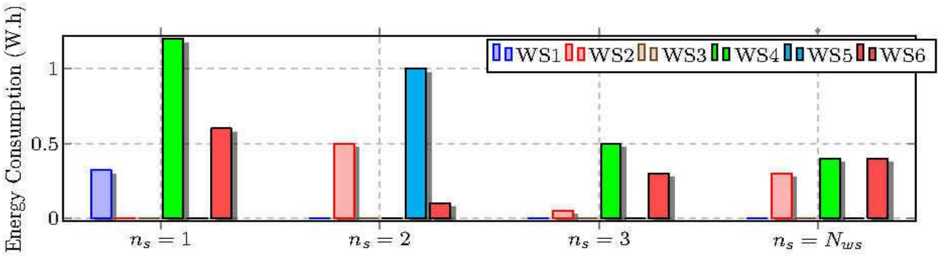


Figure 11:Energy used in workstations during a direction change process was measured by observing operating parameters in four scenarios.

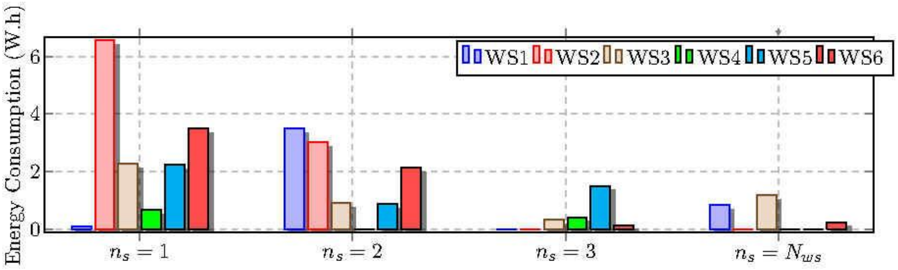


Figure 12:The energy used in machines during idle time was measured by observing the parameters

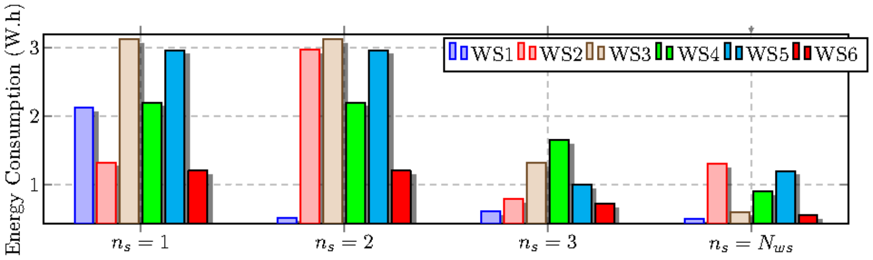
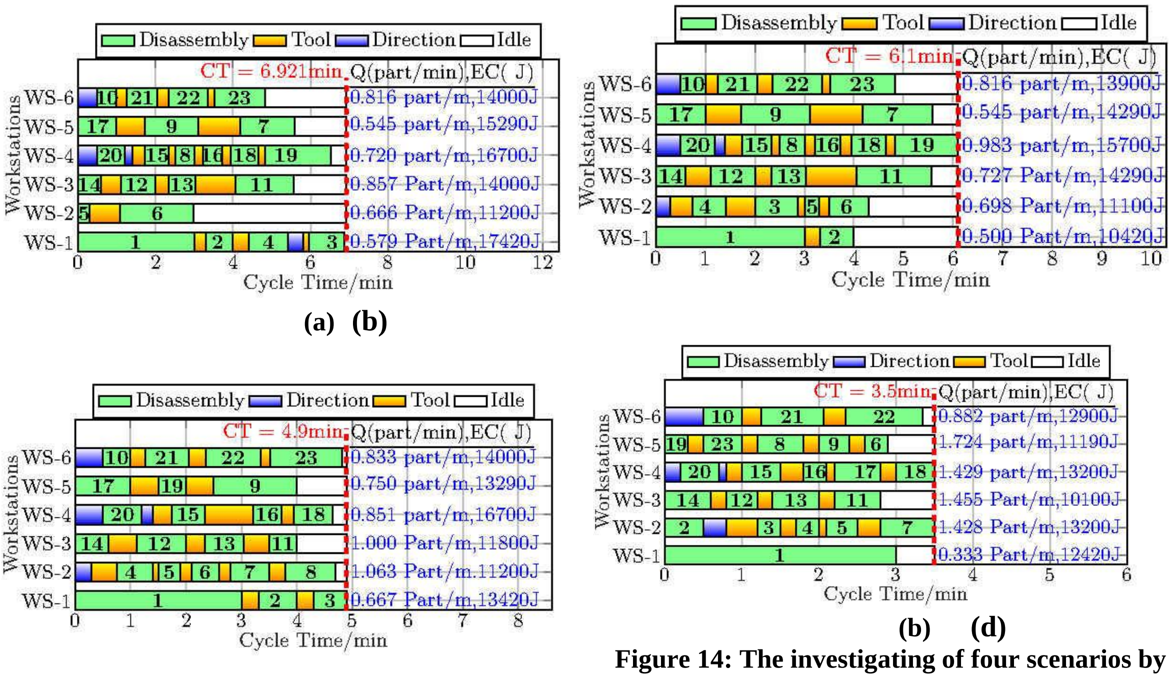


Figure 13: aggregate energy consumption used duringtools change from main tool holder to tools magazine in six workstations at four scenarios



(a) (b)

(b) (d)

Figure 14: The investigating of four scenarios by ISAA, (a) the first scenario CT =6.921min, (b) the second scenario CT =6. 1min, (c) the third scenario CT =4.9 min, (d) the fourth scenario CT =3.5 min.

Table 6: The optimum results for proposed four scenarios of four objectives of the automatic workstations at the disassembly line .

Scenarios	The best schemes detected by proposed algorithm
ns=1	{1,2,4,3}→{5,6}→{14,12,13,11}→{20,15,11,16,18,19}→{17,9,7}→{10,21,22,23}
ns =2	{1,2}→{4,3,5,6}→{14,12,13,11}→{20,15,8,16,18,19}→{17,9,7}→{10,21,22,23}
ns=3	{1,2,3}→{4,5,6,7,8}→{14,12,13,11}→{20,15,16,18}→{17,19,9}→{10,21,22,23}.
Ns=6	{1}→{2,3,4,5,7}→{14,12,13,11}→{20,15,16,17,18}→{19,23,8,9,6}→{10,21,22}

XI. CONCLUSION

It was observed that the According proposed method concerns by dividing serial disassembly line to multi sections, every section contains CNC disassembly machine, pick and place robot, and buffer boxes for EOL products need to disassembling and parts after disassembly, this method will be improve the disassembly operations, direction changing of EOL products, tool changing by the tool holder controlling by CNC control unit. This method lead to improve productivity and reduce energy consumption, side by side the cycle time and idle time will be reduction as far as workstations at optimum number to work all the time without stop because machine work automatically. Proposed SSADLBP considered useful when we convert from manual to automate disassembly line, there are many of the benefits will be gained from reducing the labor, reducing the risk of hazardous materials to workers, and operating work stations throughout the day thus we obtain good output in disassembly line as well as good balance without big problems. ISAA who proposed in this paper to investigate initial population and observed the vectors and constrains, and applied in one EOL product example was took not forever, but yet to study balancing disassembly and to and to note the problems that occur during disassembly processes. The SSADLBP model indicates the dividing of disassembly line to sections (n_s) leads to increase productivity between 400%~500%, decrease energy consumption between 50%~75%, decrease the number of workstations between 80%~95%, and decrease cycle time between 70%~85%

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