Al-Qadisiyah Journal for Engineering Sciences 14 (2021) 214–219

Contents lists available at http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: https://qjes.qu.edu.iq

Using work factor method for operational models of disassembly and reassembly evaluation

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A R T I C L E I N F O

Article history:
Received 05 May 2021
Received in revised form 09 August 2021
Accepted 22 November 2021

Keywords:
Dis/re-assemblability
Dis/reassembly sequencing
Modeling
Maintenance
Recycling
Operational context

A B S T R A C T

The purpose of this paper is to study the disassembly task time in the maintenance and recycling context, knowing that only the reassembly task is needed in repairing operation. Dis/reassembly activities are delicate and need precise intervention due to the obligation of equipment refunctioning constraints. Time spent for dis/reassembling faulty components should be well-deducted and standardized. It is not always the case due to the various variant disassembly metrics and contexts. The Work Factor Method during dis/reassembly activities helps to develop the operational dis/reassembly time models. Two model cases have been proposed. The first model presents a function of *n* components with the same characteristics that multiply the corresponding time for a component in the context where the tool used is the robot, while the second model meets the conditions of manual disassembly where the proposed function estimates the time of disassembly and reassembly according to the coefficients of performance of technician. These models contribute to defining effective time as far as operational dis/reassembly activity is concerned and can help to optimize maintenance and recycling task planning.

1. Introduction

The purpose of this paper is to study the disassembly task time in the maintenance and recycling context, knowing that only the reassembly task is needed in repairing operation. Dis/reassembly activities are delicate and need precise intervention due to the obligation of equipment refunctioning constraints. Time spent for dis/reassembling faulty components should be well-deducted and standardized. It is not always the case due to the various variant disassembly metrics and contexts. During dis/reassembly activities, the Work Factor Method is used to develop the operational dis/reassembly time model. These models contribute to defining effective time as far as operational dis/reassembly activity is concerned and can help to optimize maintenance and recycling task planning. When a failure arises, intervention is required. This process is subdivided into many intervals of time for the localization of the fault, diagnostic time, disassembly time, reparation/replacement time, reassembly time, control and final test time, and the other extra times (administrative, logistic, or awaiting for the

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https://doi.org/10.30772/qjes.v14i4.788

Nomenclature

t	the disassembly or reassembly time (s)	T_{pr}	Post-processing time of disassembly or pre-processing time of reassembly
λ	the disassembly or reassembly rate	n	Final state
n	Number of fasteners or components	x	state
$TT_{D/R}$	Total Time of Disassembly or Reassembly	i	State rank in a disassembly sequence
T_p	The preparation time of disassembly or reassembly	k_1, k_2	Performance score
T_m	Moving Time		
$T_{d/r}$	Operation time of disassembly or reassembly		

necessary resources, for the preparation of work) [1]. These times encompass TTR (Time to Repair), and they are known to be heavy and do. not permit quick availability of the faulty equipment. In this light, certain managers consider maintenance to be a source of expenditure because difficulties remain to optimize intervention time [2].

Some relevant disassembly time models have been resumed in the literature [3], and none have been related to reassembly, though reassembly takes place in a maintenance situation. Design for reassembly is then not a neglected issue. Also, significant works have been carried out in recycling disassembly time for ecological and economic problems, but the context is quite different from maintenance. Maintenance should restore working conditions, which is not the case with recycling, which takes little precaution. That is why maintenance intervention time is profoundly tied to means implemented (procedures, personnel, and logistics) [4] [5] [6]. That calls for implementing flexible maintenance methods with feedback and improvement [8] [9]. Faigner recapitulated some estimation methods of the maintenance downtimes [5]. Timekeeping (timing), Random methods, Empirical estimation, Analogical Method, Deduced Methods from the MTM (Method Time Measurement), Method of the instantaneous observations, and MOST (Maynard Operation Sequence and Technique) which is the predetermined time system that provides standard time data for the performance of precisely defined motion [10] [11] [12]. There is still a need for having standard maintenance time because the quality of maintenance time records remains unsatisfactory. Therefore, controlling the effective activity times is the pyramid foundation of the maintenance management service.

The main critical activity in the maintenance task is disassembly. Disassembly has been widely studied, starting from disassembly definition to disassembly sequencing, processing, planning, and modeling [13] [14] [15]. Major works have been done in the relevant literature and indicated the evaluation criteria and methodologies that address the problem in the context of recycling, such as disassembly sequence or economic analysis [16, 25]. Various methodologies have been developed to evaluate the disassemblability of a product [3] [26] [29]. However, the disassembly spirit for maintenance is quite different from the one of recycling.

An evaluation method of disassembling time evaluation of a product using the work factor technic was proposed [30]. This analysis is done to investigate the influencing factors related to disassembly time. Factors were quantified by a movement analysis system using a work factor system, and the operation time was obtained by applying predetermined values of time-based experience on basic human movement. The disassembly time was calculated by using the standard time on the disassembly base time depending on the sequence of disassembly operations. The disassembly time of each product component is the sum of preparation time, movement time, operation time, and post-processing time (see table 1 for more details). Disassembly analysis is obtained using a work factor system table, considering moving body parts, moving distance, weight, and artificial regulation factors. This Method is not practically feasible due to many. factors encountered in disassembly and reassembly, such as human factors, equipment factors, and logistic factors.

Table 1. Influence factors on standard time [30]

Base Time	Influence factors time
Preparation Time (Tp)	Time for identifying joint elements (Tpb) Time for searching and identifying tools (Tps) Time for gripping tools (Tpg)
Movement Time (Tm)	Time for moving between joint elements (Tmd) Time for redirecting toward the side of joint elements (Td)
Operation Time/Disassembly Time (Td)	Time for aligning between tool and joint element (Tdal) Time for tool operation area (Tda) Time for basic separation of joint element (Tdb) Time for the intensity of work (Tw)
Post-processing Time (Tpr)	Time for post-processing due to weight and size of the disassembled parts (Tprsw) Time for post-processing due to movement of disassembled parts (Tprdt) Time for post-processing due to the hazard (Tprd)

Work on maintenance disassembly time was presented [31]. The method "weighted voting" allowed anonymously gathering information in a consensual manner from working group members (maintenance actor, ergonomist, designer, and expert) on criteria or parameters linked to disassembly of each module or component of an electric hand drill during disassembly.

As earlier mentioned, disassembly and reassembly are the most critical activities in analyzing the equipment maintainability during its useful life because of many uncertainties during dis/reassembly intervention as far as maintenance actors, equipment, and work environment. Precisely, the difficulty of recording effective time might be explained by the nature of human beings (maintenance actor skill), the uncertainties of dis/reassembly nature (due to corrosion, product complexity, etc.), and the equipment dis/re-assemblability decided at the design stage, the administrative Time, the logistic Time, and the unpredictable Time. That is why it is essential to know how the TTR is deducted regarding only dis/reassembly activities as the maintenance is evaluated in hourly cost. The importance of analyzing and evaluating dis/reassembly time is then a welcome issue precisely in the maintenance and recycling context.

The main objective of this work is to propose a method for determining disassembly time, taking into account practical conditions that are generally absent in theoretical and simplified models in the literature. The activity time is a fundamental parameter in maintenance, especially in case of emergency intervention. The success of an operation should be based on a realistic time that integrates the practical vicissitudes such as micro-time, the nature of the working tools, and the operator's performance. Taking these factors into account would complement the theoretical approaches of the literature. After presenting the analysis methodology based on the "Work Factor Method", a temporal analysis of the disassembly and reassembly activity times under experimental conditions will be illustrated.

2. Methodology

Selective disassembly is generally used for product maintenance. When used for repair, some components and modules are removed to ensure accessibility to other components or modules for repairing, testing, and maintaining. Here selective disassembly is always followed by reassembly, implying that damage to any disassembled component or module must be avoided. So, to deduct the maintenance dis/reassembly time, the analysis is based on the following three main steps used here: (1) dis/reassembly definition system, (2) dis/reassembly temporal analysis using Work Factor Method (see Table 1). The dis/reassembly context should be defined because the time deducted should be given with a defined context accordingly. It should be noted that dis/reassembly time depends on: Environment of work (suitable ergonomic workshop); Availability of convenient logistics; Qualified and professional degree of the operator; Level of integration of maintainability in the equipment design. Those factors bring in extra task time, which depends on the actual context of recycling and maintenance, knowing that the Work Factor Method is defined here as the basis time. Then, we deduced the extra time using the additional scoring factors in table 2 ([32].

Table 2. The evaluation system of performance rate [32]

Skill rating		
+0,15	A1	Superskill
+0,13	A2	Superskill
+0,11	B1	Excellent
+0,08	B2	Excellent
+0,06	C1	Good
+0,03	C2	Good
+0,00	D	Average
-0,05	E1	Fair
-0,10	E2	Fair
-0,16	F1	Poor
-0,22	F2	Poor
Effort rating		
+0,13	A1	Excessive
+0,12	A2	Excessive
+0,10	B1	Excellent
+0,08	B2	Excellent
+0,05	C1	Good
+0,02	C2	Good
+0,00	D	Average
-0,04	E1	Fair
-0,08	E2	Fair
-0,12	F1	Poor
-0,17	F2	Poor
Environmental condition ratings		
+0,06	A	Ideal
+0,04	B	Excellent
+0,02	C	Good
+0,00	D	Average
-0,03	E	Fair
-0,07	F	Poor
Consistency ratings		
+0,04	A	Perfect
+0,03	B	Excellent
+0,01	C	Good
+0,00	D	Average
-0,02	E	Fair

3. Results and discussion

The methodology scheme for disassembly and reassembly time for maintenance should be flexible and general. The Method is to analyze the dis/reassembly activities in the workshop practically. It should be noted that active dis/reassembly (to unscrew and to screw) time should be deducted, but some subactivities should be taken into consideration. For example, one has for disassembly (Setting in Safety, to drain to clean, to locate, to lay down, to drive out, to extract, to unfold); and for reassembly (to engage, to reset level, to unlay down, to regulate, to test, to control). Time taken by those subactivities is masked time, which should be involved in total dis/reassembly time and should be added in Work Factor deducted Time on Table 1.

3.1. A literal description of dis/reassembly

There are three types of disassembly: selective, total, and destructive. The application of each type depends on maintenance or recycling tasks. Disassemblability and reassemblability measure the degree of dis/reassembly easiness. Disassembling is an operation having to unjoin or burst a product to the components while separating the connection elements from this unit, where reassembly is the reverse operation of the assembly except in certain cases where some adjustments are necessary. The simplest way to understand the dis/reassembly system can be represented by the basic actigram through figure 1 below.

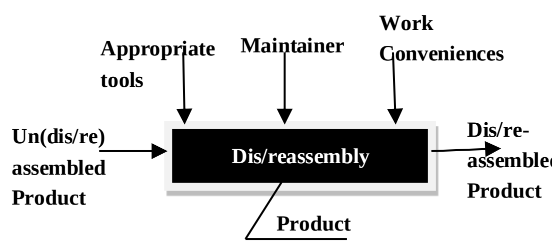

Figure 1. Basic actigram of dis/reassembly system

The average time necessary for dis/reassembling is strongly related to the time taken to dis/reassemble a screw, a bolt, or a pin. Time is not the only parameter that depends on dis/reassembly activities. It depends on other parameters which constitute the product. These parameters can be related to the equipment, maintainer, logistic and unpredictable phenomenon.

3.2. Temporal analysis of dis/reassembly activities

The dis/reassembly activity is a random task because of unpredictable events, and it is manually performed. Let us assume that disassembly is a continuous activity because when a maintenance actor engages in dis/reassembly, he cannot stop the action until he finishes the sequence operation. In such a case, the probability of the event (to remove a screw) is equal to one. This description can be randomized with the exponential law, where dis/reassembly time is the fundamental parameter. Then let us be $f(t) = \lambda e^{-\lambda t}$ the density (answer) of dis/reassembly, with $E(t) = 1/\lambda_{D/R}$ the expectation or the mean of times.
In the operational context, let us be assuming two cases that appear in disassembly and reassembly operations:

- The case wherein the equipment design, the dis/reassembly sequence was imposed according to technical specifications' mentioned in the maintenance document;

- The dis/reassembly sequence is random, i.e., the maintenance and recycling actor has his sequence to reach the target component or fastener.

A case where disassembly and reassembly sequence is imposed

In this case, the network of figure 2 as a disassembling graph is presented in the following way:

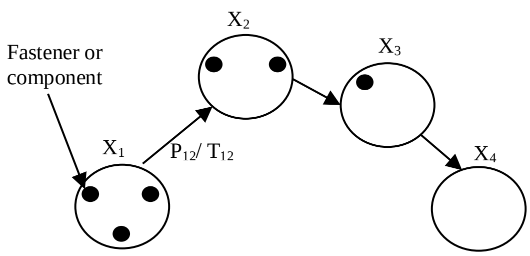

Figure 2. Imposed disassembly sequence graph

Where P_{12}: probability for losing a screw from initial state X_1 to X_2; T_{12}: Time is taken to disassemble a fastener or component from the product; X_4: complete disassembly state. Reassembly is opposite the disassembly sequence. Here, we can still distinguish two cases: the dis/reassembly operation occurs by a maintenance or recycling actor and one of the robots (electric tool).

- **Case of a robot:** If fasteners or components have the same physical parameters, the disassembly time is computed using:

$$TT_{D/R} = n \cdot \tau_{D/R} \tag{1}$$

With $\boldsymbol{\tau_{D/R}}$ Dis/Re-assembly time from ***Work Factor System*** (*Table 1*)

$$\tau_{D/R} = T_p + T_m + T_{d/r} + T_{pr} \tag{2}$$

- **Case of manual operation:** The maintenance or recycling actor is a qualified technician who follows suitable training under the activity that he should undertake. In addition, when he/she is experienced, this is appreciated by quickness, precision, quality, and the gaining of time. It must be known that the mechanical human being's energy is not constant. Therefore, the dis/reassembly force and posture are not constant along the process. Potential and kinetic energy are usually changed. The graph of figure 3 tends to illustrate the experience constituent metrics and their evolution over time.

In maintenance, the experience's operator does not relate only to the number of a year spent in the same activities, but to a chronology according to (1) basic knowledge required, (2) basic working force required, (3) basic working environment required, (4) brainstorm skill or workability and thoughtfulness, (5) working age: Time spent doing the same work, and (6) biological age. This experience has the penalty with task time. The Mean Time of Disassembling is expressed as:

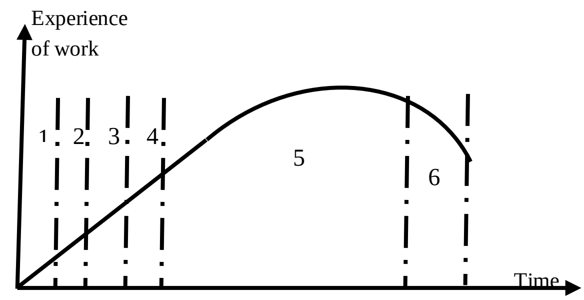

Figure 3. Experience's constituent graph over time

$$\mathrm{MT_D} = \mathrm{k_1}\left(\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{T_{x_i x_{i+1}}}\right) + \mathrm{\tau'_D} \tag{3}$$

Where: : States (i=1,2,……….n) i= state rank in a disassembly sequence $T_{x_i x_{i+1}} = \tau_D$: Time is taken to move from one state to another, corresponding to the disassembling of a fastener or the component from the initial state x_i to the next state x_{i+1}.

k_1: A score of micro-time, experience, and performance effect in the recording process time. That is defined according to table 2 and computed as illustrated in table 3.

Table 3. Summary of each performance level

Performance level	Skill rating	Effort rating	Environmental condition ratings	Consistency rating	Total Score
High	Surperskill (0.15)	Excessive (0.13)	Ideal (0.06)	Perfect (0.04)	**0.38**
Excellent	Excellent (0.11)	Excellent (0.10)	Excellent (0.04)	Excellent (0.03)	**0.28**
Good	Good (0.06)	Good (0.05)	Good (0.02)	Good (0.01)	**0.14**
Fair	Fair (0.10)	Fair (0.08)	Fair (0.03)	Fair (0.01)	**0.22**
Poor	Poor (0.22)	Poor (0.17)	Poor (0.07)	Poor (0.04)	**0.5**

Where the first score of k_1 is (high-performance score), the second is (high + excellent) scores, the third category is (The first + the second + good), the fourth is (the third + Fair), and the fifth is (the fourth + Poor performance score).

$$k_1 = \begin{cases} 0.38 & micro - time + superkill\ performance\ worker \\ 0.66 & micro - time + excellent\ performance\ worker \\ 0.8 & micro - time + good\ performance\ worker \\ 1.02 & micro - time + fair\ performance\ worker \\ 1.52 & micro - time + poor\ performance\ worker \end{cases}$$

τ'_D: Time is taken for some unexpected events (unseizing, extraction of a broken screw during disassembling, disassembly some parts with mechanism as hydraulic press, the screw is worn, cleaning, corrosion, tools inappropriate, time taken to lay down the module from the whole system, Etc.) The Mean Time of Reassembly is expressed as:

$$MT_R = k_2\left(\sum_{i=1}^{n} T_{x_i x_{i+1}}\right) + \tau'_R \tag{4}$$

Where: $T_{x_i x_{i+1}} = \tau_R$: Time takes to move from one state to another, corresponding to the reassembling of a component or a fastener
k_2: a score equal to $(\boldsymbol{k_1} + \mathbf{1})$ for each category, because of the equipment functioning requirements during reassembly operation that need task precision.

$$k_2 \begin{cases} 1.38 & micro-time + superkill\ performance\ worker \\ 1.66 & micro-time + excellent\ performance\ worker \\ 1.80 & micro-time + good\ performance\ worker \\ 2.02 & micro-time + fair\ performance\ worker \\ 2.52 & micro-time + poor\ performance\ worker \end{cases}$$

- **The case where disassembly and reassembly sequence is random:** Here, the maintenance actor should choose one of the three sequences according to the example sequence net of figure 4. Any component or fastener can be disassembled in the first stage. If the distances between the fasteners are not equidistant. Consequently, one can be interested in the shortest sequence of disassembling, which takes less time, knowing experience plays an important role.

Figure 4 below represents a network R = (X, u, d) made up of a graph G = (X, U) in which one associates a function $d: U \rightarrow R$ where each arc corresponds to its length (d(u)).

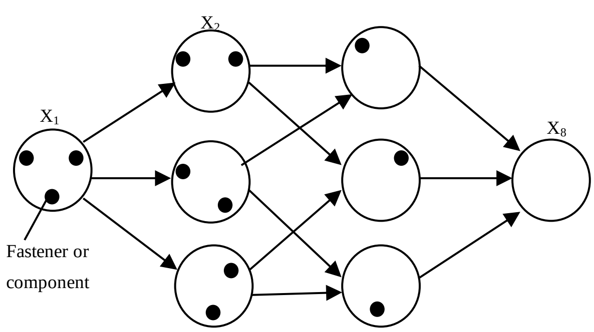

Figure 4. A network of disassembly sequence graph of three screws

The goal here is to find a way X_1 to X_8 associate with the total valuation weakest, knowing that the length of a way is equal to the sum lengths of each arc. **Ford's** algorithm is indicated for this type of graph to determine the way of optimal value because the network has only positive lengths (without circuits). The implementation of this algorithm recommends:

- To number the tops in an unspecified order (except way X_1 and X_8) ;
- $\lambda_i = +\infty$ except $\lambda_1 = 0$;
- For any top X_j for which $X_j - X_i > V(X_i, X_j)$ replace λ_j by $\lambda_i > V(X_i, X_j)$. V represents the valuation of the arc;
- To top when none λ can be modified more.

Once having the shortest way, the above dis/reassembly time formula must be applied.

3.3. Case study indication

The application of those models is based on the Work Factor System, which is already applied in [30]. Among this primary Method, this paper estimates undefined factors that occur in the operational context of dis/reassembly operations. Therefore, some additional times must be taken into consideration: call masque time, micro-time (Preparation time, tightening verification, etc.), and human experience time.

3.4. Discussion

Literature worked on disassembly for recycling to save the environment and to limit raw materials process that is generally heavy and not economically viable. Higher values can only be achieved through reuse and re-manufacturing. This research area is quite interesting, but it should not be forgotten that maintenance has a beautiful and positive impact on extending life product use.
Maintenance constitutes a vital process in the product life cycle. It refers to the work carried out to restore the degenerated performance of a system, equipment, or product to a level that is closed to a so-called 'as good as new condition. That is why disassembly for maintenance is more accurate than disassembly for recycling due to the equipment refunctioning requirements. Then, the philosophy of disassembly for recycling is different from the maintenance one, where precautions should be taken to upgrade the working condition of faulty equipment, as illustrated in Table 4.

Table 4. Differences between disassembly for recycling and for repairing

Criteria	Disassembly for repairing	disassembly for recycling
Human factors	-should be qualified	-not always
	-experiences required	-sometimes
	-upgrade faulty equipment	-no
Equipment	-in useful life	-end-of-life state
Reassembly	-unavoidable	-not required
Tools	-special tools	-not required sometimes
Time	-selective(partial) disassembly	-total disassembly
	-total disassembly in a revision case	
Environment required	-ergonomic workshop required	-disassembly process line

Some partial literature works propose methods to determine the maintenance mean time to repair in the equipment downtime period, but these fail on preciseness how time is deducted. Because the disassembly context is variant and depends on some extra parameters affecting operational task time, this paper tends to highlight the flexible and precise operational task time either for maintenance or recycling. Then the masked time that appears in the maintenance operations has been considered.

4. Conclusion and perspectives

This work aims to model and evaluate the actual maintenance and recycling deduction time. Time becomes the fundamental parameter for maintenance and recycling evaluation because this is related to cost. Among the repairing operation process, disassembly and reassembly appear relevant. A comprehensive method analysis for modeling and estimating dis/reassembly time in maintenance issues have been structured. Two aspects are highlighted: robotic and human dis/reassembly time models, knowing that dis/reassembly activities are still human. The result is prominent at the product used or at the product end-of-life stages. Measuring task time involves efficient recycling and maintenance scheduling and planning. Future work should compare the gap between theoretical and practical task time models.

Declaration of competing interest
The authors declare no conflicts of interest.

Funding source

This study didn't receive any specific funds.

REFERENCES

[1] François Monchy, Maintenance : méthodes et organisation, DUNOD, Paris, (2000). P. 509.

[2] Laloux Guillaume, (2009). "Management de la maintenance selon l'ISO 9001: 2008 ", © AFNOR Éditions 2009, www.afnor.org, P. 139

[3] Ali, Ammar, "PRODUCT DISASSEMBLABILITY AND REMANUFACTURABILITY ASSESSMENT: A QUANTITATIVE APPROACH" Theses and Dissertations--Mechanical Engineering. (2017). 109.

[4] Faigner, (2013). (www.hubertfaigner.com/)

[5] Wolfgang NZIE, Intégration de la maintenance en conception : application à un équipement agroalimentaire. Thèse de Doctorat, École Doctorale Sciences pour l'Ingénieur et Microtechniques Université de Technologie de Belfort-Montbéliard Université de Besançon, (2006). 27 Février P.132

[6] Al-Najjar, B., Alsyouf, I. Selecting the Most Efficient Maintenance Approach Using Fuzzy Multiple Criteria Decision Making. International Journal of Production Economics, (2003). Vol. 84, No. 1, 85-100.

[7] Waeyenbergh, G. and Pintelon, L. Maintenance Concept Development: A Case Study. International J. of Production Economics, (2004). Vol. 89, 395-405.

[8] Li *and al.,* A Novel Representation Scheme for Disassembly Sequence Planning, International Journal Advance Manufacturing Technology (2002). 20:621–630

[9] Kroll, E., Application of work-measurement analysis to product disassembly for recycling, Concurrent Engineering: Research and Applications (1996). 4 (2): 149 –157.

[10] Boks CB, Brouwers WCJ, Kroll E, Stevels ALN, Disassembly modeling: two applications to a Philips 21 &&television set, Proc. IEEE Int. Symp. on Electronics and the Environment, Dallas, TX, (1996). 224-9.

[11] Zandin, KB., MOST work measurement system, Marcel Dekker.Inc., (2003). New York.

[12] Westkamperl, Platform for the Integration of Assembly, Disassembly and Life Cycle Management, CIRP Annals - Manufacturing Technology, (2002). Volume 51, Issue 1 Pages 33–36

[13] https://uknowledge.uky.edu/me_etds/109.DigitalObjectIdentifer: https://doi.org/10.13023/ETD.2017.502

[14] A.J.D. (Fred) Lambert, Surendra M. Gupta, Disassembly modeling for assembly, maintenance reuse, and recycling, CRC Press, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431. (2005). P. 446

[15] Surendra M. Gupta*, Kendra E. Moore*' and Askiner Gungor*, A Petri Net Approach to Disassembly Process Planning, Computers ind. Engng Vol. 35, (1998). Nos 1-2. pp. 165-168,

[16] Mok *et al.,* Disassemblability of mechanical parts in Automobile for Recycling, Computers Ind. Eng. (1997). Vol.33, No3-4, P. 621-624

[17] Zhang, H.C., Kuo, T.C., Lu, H., Huang, S., Environmentally conscious design and manufacturing: a state-of-the-art survey. Journal of Manufacturing Systems (1997). 16 (5), 352–371.

[18] Lambert, A.J.D., Linear programming in disassembly/clustering sequence generation. Computers and Industrial Engineering (1999). 36, 723–738.

[19] Brennan, L., Gupta, S.M., Taleb, K.N., Operations planning issues in an assembly/disassembly environment. International Journal of Operations and Production Management (1994). 14 (9), 57–67.

[20] Gungor, A., Gupta, S., An evaluation methodology for disassembly process. Computers and Industrial Engineering (1997). 33 (1–2), 329–332.

[21] Thierry, M., Salomon, M., Van Nunen, J., Van Wassenhowe, L., Strategic issues in product recovery management. California Management Review (1995). 37 (2), P. 114–135.

[22] Krikke, H.R., Harten, A., Schuur, P.C., On a medium-term recovery and disposal strategy for durable assembly products. International Journal of Production Research 36 (1), (1998). P. 111–139.

[23] Gungor, A., Gupta, S., Disassembly sequence planning in products with defective parts in product recovery. Computer and Industrial Engineering (1998). 35 (1–2), 161–164.

[24] Feri Afrinaldi *et al.,* The evaluation methods of disassemblability for automotive components – a review and agenda for future research », Jurnal Mekanikal, (2008). No 26, P. 49 – 62;

[25] Karolina Kazmierczak, W. Patrick Neumann, Jørgen Winkel, A Case Study of Serial-Flow Car Disassembly: Ergonomics, Productivity, and Potential System Performance, Human Factors and Ergonomics in Manufacturing, (2007). Vol. 17 (4) P.331–351

[26] Anil Mital, and Anoop Desai. Evaluation of disassemblability to enable design for disassembly in mass production, International Journal of Industrial Ergonomics, (2003). Vol 32 P. 265-281;

[27] Kroll, E., McGlothlin, S., Systematic estimation of disassembly difficulties: application to computer monitors, IEEE International Symposium on Electronics & the Environment, (1995), P. 83-88

[28] Kondo, Y., Deguchi, K., Hayashi, Y., Obata, F., Reversibility and disassembly time of part connection, Resources Conservation and Recycling (2003). 38, 175 – 184

[29] Surendra M. Gupta, and Askiner Gungor, An Evaluation Methodology for Disassembly Processes, Computers ind. Engng (1997). Vol. 33, Nos 1-2, pp. 329-332,

[30] Kroll, E., Carver, B., Disassembly analysis through time estimation and other metrics, Robotics and Computer Integrated Manufacturing (1999). 15, P. 191–200.

[31] Yi, HC., Park, YC., Lee, KS., A study on the Method of disassembly time evaluation of a product using work factor method, International conference on systems, man and cybernetics, (2003). vol 2, pp : 1753 – 1759.

[32] Samon *and al.,* A New Methodology Approach of Disassemblability Evaluation of an Equipment Improving Maintenance, European Journal of Scientific Research, ISSN 1450-216X (2012). Vol.72 No.3 pp. 394-403.

[33] Niebel, B., *Time Study,* in Handbook of Industrial Engineering, 2nd Ed., G. Salvendy, Ed., John Wiley & Sons, New York, (1992). pp. 1599–1638