

MANUAL HANDLING-ESTIMATED TIMES (S)

Satu Tangan (satuan mm)	Ambil dan Mengarahkan Mudah				Ambil dan mengarahkan susah					
	Tebal >2		Tebal ≤2		Tebal >2		Tebal ≤2			
	Panjang >15	Panjang ≤6	Panjang >6	Panjang ≤6	Panjang >15	Panjang ≤6	Panjang >6	Panjang ≤6		
	0	1	2	3	4	5	6	7	8	9
($\alpha + \beta$) < 360°	0	1,13	1,88	1,69	2,18	1,84	2,17	2,65	2,45	2,98
360° ≤ ($\alpha + \beta$) < 540°	1	1,5	2,25	2,06	2,55	2,25	2,57	3,06	3	3,38
540° ≤ ($\alpha + \beta$) < 720°	2	1,8	2,55	2,36	2,85	2,57	2,9	3,38	3,18	3,7
($\alpha + \beta$) = 720°	3	1,95	2,25	2,7	2,51	3	2,73	3,06	3,34	4

Satu Tangan dan Alat (satuan mm)	Perlu pinset untuk mengambil dan mengarahkan										
	Tidak perlu alat optik pembesar					Perlu alat optik pembesar					Alat khusus untuk ambil & mengarahkan
	Ambil dan mengarahkan mudah		Ambil dan mengarahkan sulit (1)		Ambil dan mengarahkan mudah		Ambil dan mengarahkan sulit (1)		Butuh alat bukan pinset		
	0	1	2	3	4	5	6	7	8	9	
($\alpha + \beta$) < 360°	4	3,6	6,85	4,35	7,6	5,6	8,35	6,35	8,6	7	
360° ≤ ($\alpha + \beta$) < 540°	5	4	7,25	4,75	8	6	8,75	6,75	9	8	
540° ≤ ($\alpha + \beta$) < 720°	6	4,8	8,05	5,55	8,8	6,8	9,55	7,55	9,8	9	
($\alpha + \beta$) = 720°	7	5,1	8,35	5,85	9,1	7,1	9,55	7,85	10,1	10	

Dua tangan Manipulasi (2)	Tidak ada extra problem mengarahkan										Extra problem mengarahkan (goyang, lengket, licin, dsj)	
	$\alpha \leq 180^\circ$					$\alpha = 180^\circ$					$\alpha \leq 180^\circ$	
	Panjang > 15	6 > panjang < 15	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6	Panjang > 6
	0	1	2	3	4	5	6	7	8	9		
Komponen goyang atau flexibel tapi harus diambil dengan satu tangan, jika perlu dengan alat (2) dan tangan kedua untuk melepas	8	4,1	4,5	5,1	5,6	6,75	5	5,25	5,85	6,35	7,0	

Komponen besar 2 tangan	Mengarahkan oleh 1 orang tanpa alat bantu mekanik										2 orang atau perlu alat bantu mekanik
	Tidak Goyang, Tidak Fleksibel					Goyang atau flexible					
	Berat ≤ 5Kg		Berat > 5Kg			Berat ≤ 5Kg		Berat > 5Kg			
	0	1	2	3	4	5	6	7	8	9	
Ambil dan memindahkan dengan 2 tangan, 2 orang atau alat bantu mekanik	9	2	3	2	3	3	4	4	5	5	7

Diadaptasi dari
Boothroyd, Dewhurst, dan Knight, (2010)
Halaman 84

MANUAL INSERTION-ESTIMATED TIMES (S)

Komponen Tidak Langsung Melekat		Tidak perlu dipegang setelah dimasukkan (3)			
		Pemasangan mudah (4)		Pemasangan susah (4)	
Komponen tidak dapat langsung dipasang	Tempat memasukkan mudah di jangkau	0	1	2	3
	Tempat memasukkan sulit	1	5	5	6
		2	6,5	6,5	7,5
		0	1	2	3
		1,5	2,5	2,5	3,5
		4	5	5	6
		5,5	6,5	6,5	7,5

Komponen Tidak Langsung Melekat		Perlu dipegang setelah dimasukkan (3)			
		Pemasangan mudah (4)		Pemasangan susah (4)	
Komponen tidak dapat langsung dipasang	Tempat memasukkan mudah di jangkau	6	7	8	9
	Tempat memasukkan sulit	7	9	9	10
		8	10,5	10,5	11,5
		5,5	6,5	6,5	7,5
		8	9	9	10
		9,5	10,5	10,5	11,5

Komponen Langsung Melekat		Deformasi Plastik Langsung setelah dimasukkan										
		Torsi / Bending Plastik		River (link) atau sejenisnya								
Komponen tidak dapat langsung dipasang	Tempat memasukkan mudah di jangkau	0	1	2	3	4	5	6	7	8	9	
	Tempat memasukkan sulit	1	5	5	6	6	6	6	7	8	9	
		2	6,0	9,0	8,0	10,0	11,0	12,0	13,0	10,0	10,0	12,0
			3	5	4	5	5	5	6	7	8	9
			4,5	7,5	6,5	7,5	8,5	9,5	10,5	11,5	8,5	10,5
		5	9,0	8,0	9,0	10,0	11,0	12,0	13,0	10,0	12,0	

Proses Terpisah		Penggancang Secara mekanis tersedia tapi tidak langsung kencana				Penggancang non mekanis tersedia tapi tidak langsung kencana				
		Tidak ada Deformasi plastik lokal		Bulk Plastic deformation (komponen dalam jumlah besar deformasi plastik saat pengikatan)		Tidak ada penambahan material solder		Diproses secara kimiawi misalnya lem		
Proses perakitan dimana seluruh komponen telah terpasang, tidak ada komponen lain atau sub	0	1	2	3	4	5	6	7	8	9
	4,0	7,0	5,0	12,0	7,0	5,0	12,0	12,0	9,0	12,0
	9									

Diadaptasi dari
Boothroyd, Dewhurst, dan Knight, (2010)
Halaman 84

LAMPIRAN 3

Hasil Analisis DFMA Robot Lengan Rancangan Lama

0	1	2	3	4	5	6	7	8	9	10			
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0, 4 x (7)	Figures for estimation of theoretical minimum	Name of Assembly			
Bagian 5	1	1	0	0	1,13	0	0	1,5	2,63	1,052	1	Bracket Servo 5	
	2	1	0	0	1,13	3	2	4	5,13	2,052	1	ISO 7046-1 - M3 x 12 - Z --- 12S	
	3	1	0	2	1,88	0	0	1,5	3,38	1,352	1	Washer ISO 7089 - 3	
	4	1	0	0	1,13	3	0	2	3,13	1,252	1	Hand Clamp	
	5	1	0	2	1,88	3	8	6	7,88	3,152	1	ISO 10511-M3-S	
	6	1	0	0	1,13	0	6	5,5	6,63	2,652	1	TOWER PRO MG-90s, ANALOG SERVO, HORN_1	
	7	1	0	0	1,13	3	0	2	3,13	1,252	1	Hand Clamp Hole Gear	
	8	3	0	2	1,88	3	2	4	17,64	7,056	0	ISO 7046-1 - M1.6 x 5 - Z --- 5S	
	9	1	0	0	1,13	0	6	5,5	6,63	2,652	1	lock plate base servo 1	
	10	1	0	1	1,43	3	2	4	5,43	2,172	1	cross recessed binding head screw jis	
	11	2	3	0	1,95	0	6	5,5	14,9	5,96	0	Plate Motor Servo 5	
	12	1	3	0	1,95	0	6	5,5	7,45	2,98	1	MG90s servo	
	13	2	0	2	1,88	3	8	6	15,76	6,304	2	Hexagon Nut ISO - 4032 - M2 - D - S	
	14	1	0	1	1,43	3	2	4	5,43	2,172	1	ISO 7045 - M3 x 5 - Z --- 5S	
	15	2	0	1	1,43	3	2	4	10,86	4,344	2	JIS 1111 Cross recessed countersunk head screw - M2 x 16 - Z --16S	
20										116,01	46,404	15	38,79%
										Tm	Operati on cost	Nm	$Efficiency = \frac{Nm * 3 (estimation theory in second)}{Tm} * 100$

0	1	2	3	4	5	6	7	8	9	10			
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0, 4 x (7)	Figures for estimation of theoretical minimum	Name of Assembly			
Bagian 4	1	1	3	0	1,95	3	4	6	7,95	3,18	1	Bracket Servo 4	
	2	1	0	0	1,13	0	6	5,5	6,63	2,652	1	TOWER PRO MG-90s, ANALOG SERVO, HORN_1	
	3	1	0	2	1,88	3	3	5	6,88	2,752	0	countersunk flat head cross recess screw_ison	
	4	1	3	0	1,95	0	6	5,5	7,45	2,98	1	MG90s servo	
	5	2	0	1	1,43	3	2	4	10,86	4,344	2	ISO 7045 - M2 x 12 - Z --- 12S	
	6	2	4	2	4,35	4	8	8,5	25,7	10,28	2	Hexagon Nut ISO - 4036 - M2 - S	
	7	1	0	2	1,88	1	8	9	10,88	4,352	1	ISO 10669-3-N	
	8	1	0	0	1,13	3	2	4	5,13	2,052	1	JIS B 1111 Binding head screw M3 x 12 --12S	
	9	1	0	2	1,88	4	8	8,5	10,38	4,152	1	ISO 7040-M3-S	
	10	1	0	2	1,88	3	2	4	5,88	2,352	1	ISO 7045 - M2.5 x 4 - Z --- 4S	
12										97,74	39,096	11	34%
										Tm	Operati on cost	Nm	$Efficiency = \frac{Nm * 3 (estimation theory in second)}{Tm} * 100$

0	1	2	3	4	5	6	7	8	9	10			
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0, 4 x (7)	Figures for estimation of theoretical minimum	Name of Assembly			
Bagian 3	1	1	3	0	1,95	3	4	6	7,95	3,18	1	Bracket penghubung Servo 2 ke servo 3	
	2	1	3	0	1,95	0	6	5,5	7,45	2,98	1	Bracket Servo 3	
	3	2	0	1	1,43	3	2	4	10,86	4,344	0	cross recessed binding head screw jis	
	4	2	0	2	1,88	3	8	6	15,76	6,304	0	JIS B 1181 Hexagon nut - style 1 A M2 - D --S	
	5	1	0	0	1,13	0	6	5,5	6,63	2,652	1	Washer Clamp Motor Servo 2	
	6	1	0	2	1,88	3	2	4	5,88	2,352	0	JIS B 1111 Truss head screw M2 x 5 --5S	
	7	1	3	6	3,06	0	6	5,5	8,56	3,424	1	MG90s servo	
	8	2	0	1	1,43	3	2	4	10,86	4,344	2	ISO 7045 - M2 x 12 - Z --- 12S	
	9	1	0	2	1,88	3	2	4	5,88	2,352	2	cross recessed binding head screw jis	
	10	1	0	1	1,43	3	2	4	5,43	2,172	1	cross recessed binding head screw jis	
	11	2	0	2	1,88	3	8	6	15,76	6,304	2	Hexagon Nut ISO - 4036 - M2 - S	
	13	1	0	2	1,88	4	8	8,5	10,38	4,152	1	JIS B 1181 Hexagon nut - style 1 A M2 - D --S	
	16										101,02	40,408	12
										Tm	Operati on cost	Nm	$Efficiency = \frac{Nm * 3 (estimation theory in second)}{Tm} * 100$

LAMPIRAN 4

Hasil Analisis DFMA Robot Lengan Rancangan Lama

0	1	2	3	4	5	6	7	8	9	10	
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second $(2) \times [(4) + (6)]$	Operation cost, cents $0.4 \times (7)$	Figures for estimation of theoretical minimum	Name of Assembly	
Bagian 2	1	2	0 1	1,43	3 2	4	10,86	4,344	0	JIS 1111 Cross recessed countersunk head screw - M2 x 1010S	
	2	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Bracket Servo 2	
	3	2	0 3	1,69	3 8	6	15,38	6,152	0	JIS B 1181 Hexagon thin nut - double chamfered A M2 -S	
	4	1	3 6	3,06	0 6	5,5	8,56	3,424	1	TOWER PRO MG995	
	5	4	0 2	1,88	0 0	1,5	13,52	5,408	0	ISO 10669-3.55-N	
	6	4	0 1	1,43	3 2	4	21,72	8,688	4	ISO 7045 - M3 x 10 - Z -- 10S	
	7	2	0 3	1,69	3 8	6	15,38	6,152	2	Hexagon Thin Nut ISO - 4035 - M3 - S	
	8	2	0 3	1,69	4 8	8,5	20,38	8,152	2	Hexagon Thin Nut ISO - 4035 - M3 - S	
							108,43	43,372	10	28%	
							Tm	Operati on cost	Nm	$Efficiency = \frac{Nm * 3 (estimation theory in second)}{Tm} \times 100$	

0	1	2	3	4	5	6	7	8	9	10	
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second $(2) \times [(4) + (6)]$	Operation cost, cents $0.4 \times (7)$	Figures for estimation of theoretical minimum	Name of Assembly	
BAGIAN 1	1	2	0 1	1,43	3 2	4	10,86	4,344	2	B18.6.7M - M2 x 0.4 x 13 Type I Cross Recessed PHMS-13S	
	2	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Base Plate Servo 1	
	3	2	3 0	1,95	0 6	5,5	14,9	5,96	0	Plate Motor Servo 5	
	4	1	3 0	1,95	0 6	5,5	7,45	2,98	1	MG90s servo	
	5	2	0 2	1,88	3 8	6	15,76	6,304	2	Hexagon Thin Nut ISO - 4035 - M2 - S	
							51,6	20,64	6	35%	
							Tm	Operati on cost	Nm	$Efficiency = \frac{Nm * 3 (estimation theory in second)}{Tm} \times 100$	

0	1	2	3	4	5	6	7	8	9	10	
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second $(2) \times [(4) + (6)]$	Operation cost, cents $0.4 \times (7)$	Figures for estimation of theoretical minimum	Name of Assembly	
Bagian Board Control	1	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Base	
	2	5	0 2	1,88	3 0	2	19,4	7,76	0	Rubber Pad	
	3	1	0 0	1,13	0 6	5,5	6,63	2,652	1	lock plate base servo 1	
	4	4	0 2	1,88	3 2	4	23,52	9,408	0	ISO screw M1,6	
	5	4	0 1	1,43	3 2	4	21,72	8,688	0	Spacer M3X10	
	6	4	0 2	1,88	3 8	6	31,52	12,608	4	Hexagon Thin Nut ISO - 4035 - M3 - S	
	7	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Arduino	
	8	4	0 2	1,88	3 2	4	23,52	9,408	4	B18.6.7M - M2 x 0.4 x 4 Type I Cross Recessed PHMS -4S	
	9	1	0 1	1,43	3 2	4	5,43	2,172	1	B18.6.7M - M2 x 0.4 x 4 Type I Cross Recessed PHMS -4S	
	10	1	0 0	1,13	3 1	5	6,13	2,452	1	Board Control	
							143,13	57,252	13	27%	
							Tm	Operati on cost	Nm	$Efficiency = \frac{Nm * 3 (estimation theory in second)}{Tm} \times 100$	

Sub-Assembly	Jumlah Komponen		Efisien si	Waktu Total Perakitan (Tm) " detik "	Nm Total
	Sebenarnya	TEORI			
Bagian 5	20	15	38,79%	10,299 MENIT	67
Bagian 4	12	11	34%		
bagian3	16	12	36%		
bagian 2	18	10	28%		
bagian 1	8	6	35%		
Bagian board control	26	13	27%	Total Efisiensi Perakitan (NM)	Total Operation Cost
Total Part	100	67		32,53%	247,172

LAMPIRAN 5

Hasil Analisis DFMA Robot Lengan Rancangan Baru

0	1	2	3	4	5	6	7	8	9	10
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0.4 x (7)	Figures for estimation of theoretical	Name of Assembly
Bagian 5	1	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Bracket Servo 1
	2	2	0 0	1,13	0 6	5,5	13,26	5,304	2	TOWER PRO MG-90s, ANALOG SERVO, HORN_1
	3	2	0 1	1,43	3 2	4	10,86	4,344	2	ISO 7045 - M3 x 5 - Z --- 5S
	4	1	0 0	1,13	3 2	4	5,13	2,052	1	ISO 7046-1 - M3 x 16 - Z --- 16S
	5	1	3 0	1,95	0 6	5,5	7,45	2,98	1	MG90s servo
	6	2	0 1	1,43	3 2	4	10,86	4,344	2	ISO 7046-1 - M2 x 12 - Z --- 12S
	7	2	0 2	1,88	3 8	6	15,76	6,304	2	Hexagon Thin Nut ISO - 4035 - M2 - S
	8	1	0 2	1,88	0 0	1,5	3,38	1,352	1	ISO 10673-3.2-N
	9	1	0 0	1,13	3 0	2	3,13	1,252	1	griper
	10	1	0 2	1,88	3 2	4	5,88	2,352	1	ISO 10511-M3-S
	11	1	0 1	1,43	3 2	4	5,43	2,172	1	ISO 7046-1 - M2 x 5 - Z --- 5S
	12	1	0 0	1,13	3 0	2	3,13	1,252	1	Gripper Hole Gear
16							86,9	34,76	16	55%
							Tm	Operati on cost	Nm	

0	1	2	3	4	5	6	7	8	9	10
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0.4 x (7)	Figures for estimation of theoretical	Name of Assembly
Bagian 4 -3	1	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Bracket Servo 3.1
	2	2	3 0	1,95	0 6	5,5	14,9	5,96	2	MG90s_servo
	3	2	0 4	2,18	3 2	4	12,36	4,944	2	Hexagon Thin Nut ISO - 4035 - M2 - S
	4	4	0 1	1,43	3 2	4	21,72	8,688	4	ISO 7046-1 - M2 x 12 - Z --- 12S
	5	2	0 4	2,18	3 8	6	16,36	6,544	2	Hexagon Thin Nut ISO - 4035 - M2 - S
11							67,97	27,188	11	49%
							Tm	Operati on cost	Nm	

0	1	2	3	4	5	6	7	8	9	10
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0.4 x (7)	Figures for estimation of theoretical	Name of Assembly
Bagian Lengan Penghubung	1	1	0 0	1,13	0 1	2,5	3,63	1,452	1	Lengan penghubung
	2	2	0 0	1,13	0 6	5,5	13,26	5,304	2	TOWER PRO MG-90s, ANALOG SERVO, HORN_1
	3	2	0 2	1,88	3 2	4	11,76	4,704	2	ISO 7045 - M3 x 5 - Z --- 5S
5							28,65	11,46	5	52%
							Tm	Operati on cost	Nm	

LAMPIRAN 6

Hasil Analisis DFMA Robot Lengan Rancangan Baru

0	1	2	3	4	5	6	7	8	9	10
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0.4 x (7)	Figures for estimation of theoretical	Name of Assembly
BAGIAN 2	1	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Bracket Servo 2.1
	2	2	0 1	1,43	3 2	4	10,86	4,344	2	ISO 7046-1 - M2 x 12 - Z --- 12S
	3	1	3 6	3,06	0 6	5,5	8,56	3,424	1	MG90s servo
	4	2	0 2	1,88	3 8	6	15,76	6,304	2	Hexagon Thin Nut ISO - 4035 - M2 - S
	5	1	0 0	1,13	0 6	5,5	6,63	2,652	1	Washer Clamp Motor Servo 2
	6	1	0 2	1,88	3 2	4	5,88	2,352	1	ISO 7045 - M3 x 5 - Z --- 5S
		8					50,32	20,128	8	48%
							Tm	Operati on cost	Nm	

0	1	2	3	4	5	6	7	8	9	10
Sub Assembly	Part ID No.	Number of times the operation is carried out consecutively	Two digit manual handling code	Manual handling time per part	Two-digit manual insertion handling code	Manual insertion time per part	Operation time, second (2) x [(4) + (6)]	Operation cost, cents 0.4 x (7)	Figures for estimation of theoretical	Name of Assembly
Bagian Board Control + 1	1	1	0 0	1,13	0 0	1,5	2,63	1,052	1	Base plate control
	2	1	0 0	1,13	3 1	5	6,13	2,452	1	arduino uno
	3	1	3 6	3,06	0 6	5,5	8,56	3,424	1	TOWER PRO MG995
	4	4	0 1	1,43	3 2	4	21,72	8,688	4	ISO 7045 - M3 x 10 - Z --- 10S
	5	4	0 3	1,69	3 8	6	30,76	12,304	4	Hexagon Thin Nut ISO - 4035 - M3 - S
	6	1	0 0	1,13	3 1	5	6,13	2,452	1	Board Control
		12					75,93	30,372	12	47%
							Tm	Operati on cost	Nm	

Sub-Assembly	Jumlah Komponen			Waktu Total Perakitan (Tm) " detik "	Nm Total
	Sebenarnya	TEORI	Efisiensi		
Bagian 5	16	16	55 %	309,77	52
Bagian 4-3	11	11	49 %		
Lengan Penghubung	5	5	52 %	5,162 MENIT	
bagian 2	8	8	28%		
Bagian board control	12	12	27%		
Total Part	52	52		Total Efisiensi Perakitan (NM)	Total Operation Cost
				50,36%	123,908