

# Appendix A - Ergonomics Analysis

## Zigzag Door



### Ergonomic Assessment Worksheet V1.3.4

Plant	Gender of operator m <input type="checkbox"/> f <input type="checkbox"/>	Body height
Line	MTM Analysis	Analyst
Task / Workplace <i>Zigzag</i>	Task duration [sec]	Date

**Result of overall evaluation:** Calculate the total score of the whole body sections and compare it to the upper limbs score. The overall result is determined by the higher value but integration should also take into account the second value.

<input checked="" type="checkbox"/> Green	<b>Whole Body</b>	=	<b>Postures</b>	+	<b>Forces</b>	+	<b>Loads</b>	+	<b>Extra</b>	<b>Upper Limbs</b>
<input type="checkbox"/> Yellow	19	=	16	+	3	+	n/a	+	n/a	6
<input type="checkbox"/> Red										

<b>EAWs evaluation</b>	0-25 Points	Green	Low risk: recommended; no action is needed
	>25-50 Points	Yellow	Possible risk: not recommended; redesign if possible, otherwise take other measures to control the risk
	>50 Points	Red	High risk: to be avoided; action to lower the risk is necessary


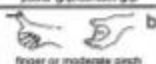

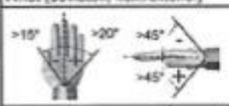
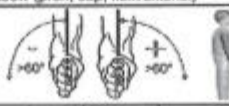
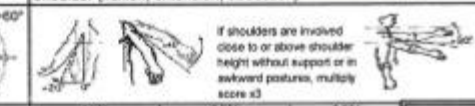
Extra points "Whole body" (per minute / shift)						Extra points		
0a	Adverse effects by working on moving objects	0	3	8	15	Intensity		
		none	middle	strong	very strong			
0b	Accessibility (e.g. entering motor or passenger compartment)	0	2	5	10	Status		
		good	complicated	poor	very poor			
0c	Countershocks, impulses, vibrations 	0	1	2	5	Intensity x frequency		
		light	visible	heavy	very heavy			
		0	1	2,5	4		5	8
0d	Joint position (especially wrist) 	0	1	3	5	Intensity x duration or frequency		
		neutral	~ 1/3 max	~ 2/3 max	maximal			
		0	2	2,5	4		6	8
		[sec]	3	10	20		40	60
	[n]	1	8	11	16	20		
	[%]	5	17	33	67	100		
0e	Other physical work load (please describe in detail)	0	5	10	15	Intensity		
		none	middle	strong	very strong			
<b>Extra = Σ lines 0a - 0e</b>		Attention: Max. score = 40 (line 0c, 0d); Max. score = 15 (line 0a, 0e); Max. score = 10 (line 0b)		Attention: correct evaluation, if duration of evaluation ≠ 60s				

*Lines 0a-b mainly relate to the Automotive Industry, for other sectors additional elements may be necessary. For details see the EAWs manual.*

For scoring of repetitive tasks only:		
Description	Formula	Result
Real shift duration [min]		
Lunch break [min]	-	
Other official pauses [min]	-	
Non repetitive tasks (i.e. cleaning, supplies, etc) [min]	-	
Net duration of repetitive task/s (a) [min]	=	
No. of real units (or cycles) (b)		
Net cycle time [sec]	(a/b x 60) =	
Observed cycle time [sec]		

Comments / proposals for improvements


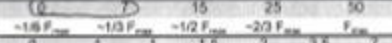

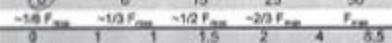
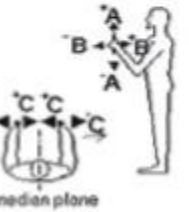
## Ergonomic Assessment Worksheet V1.3.4

Upper limb load in repetitive tasks															Upper Limbs																																																																																																					
<b>Force &amp; Frequency &amp; Grip (FFG)</b>																																																																																																																				
Basis: number of real actions per minute or percent static actions (analyze only the most loaded limb)																																																																																																																				
  																																																																																																																				
Force & Duration Grip Percentage of time involved (Force & Duration) + (Grip + Percentage of time involved) Very long lasting static actions, almost 70% Long lasting static actions, almost 50% Substantial amount of static actions - 35% Considerable amount of static actions - 25% Low amount of static actions - 15% Very low amount of static actions - 5% Good gripping conditions Moderate gripping conditions Poor gripping conditions Medium Slow arm movements, freq. about interruptions Arm movements not too fast, about interrupt Normal arm movements, but about or occasional and irregular interruptions Faster arm movements, occasional and irregular short pauses Continuous arm movements. Lack of interruptions make difficulties to keep pace Very high frequencies, absolutely no interruptions None Force & Frequency + Grip Percentage of time involved (Force & Frequency) + (Grip + percentage)																																																																																																																				
Force [N]		Calc Stat			Static actions (sec/min)					Grip				Dynamic actions (real actions/min)					Calc Dyn																																																																																																	
		FFS	GS	%	FFGp	≥45	30	20	10	5	3	0	2	4	5	10	15	20	25	30	35	≥40	FFG	%	FFGp																																																																																											
0 - 5						1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7																																																																																														
> 5 - 20		1	2	100	3	4	2	1	0	0	0	ab	bc		0	0	1	2	3	4	6	9																																																																																														
> 20 - 35						7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12																																																																																														
> 35 - 90						11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18	3	100	3																																																																																											
> 90 - 135						16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24																																																																																														
> 135 - 225						21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32																																																																																														
> 225 - 300						28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40																																																																																														
20a		FFGS = Σ FFGp			100%			3			FFG = FFGS + FFGD					6			FFG			NDA = 1-FFG			FFGD = Σ FFGp			NDA		3																																																																																						
<b>Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)</b>																																																																																																																				
Wrist (deviation, flex./extens.)								Elbow (pron, sup, flex./extens.)								Shoulder (flexion, extension, abduction)																																																																																																				
																																																																																																																				
Posture points								10% 25% 33% 50% 65% 85%								0 0.5 1 2 3 4												PP																																																																																								
<b>Additional factors</b>																																																																																																																				
Gloves inadequate (which interfere with the handling ability required) are used for over half the time <span style="float: right;">2 <input type="checkbox"/></span> Working gestures required imply a countershock. Frequency of 2 time per minute or more (i.e.: hammering over hard surface) <span style="float: right;">2 <input type="checkbox"/></span> Working gestures imply a countershock (using the hand as a tool) with freq. of 10 time per hour or more <span style="float: right;">2 <input type="checkbox"/></span> Exposure to cold or refrigeration (less than 0 degree) for over half the time <span style="float: right;">2 <input type="checkbox"/></span> Vibrating tools are used for 1/3 of the time or more <span style="float: right;">2 <input type="checkbox"/></span> Tools with a very high level of vibrations <span style="float: right;">4 <input type="checkbox"/></span> Tools employed cause compressions of the skin (rednesses, callosities, blebs, etc.) <span style="float: right;">2 <input type="checkbox"/></span> Precision tasks are carried out for over half the time (tasks over areas smaller than 2-3 mm) <span style="float: right;">2 <input type="checkbox"/></span> More than one additional factor is present at the same time and overall occupy the whole of the time <span style="float: right;">3 <input type="checkbox"/></span> Additional points (choose the highest value) = <span style="float: right;">AF</span>																																																																																																																				
<b>Repetitive tasks duration</b>																																																																																																																				
Duration (h/shift) <span style="float: right;">+</span> Duration Points <span style="float: right;">+</span> Work Organization <span style="float: right;">+</span> Work Organization Points <span style="float: right;">+</span> Breaks (≥ 8 min) (h/shift) <span style="float: right;">+</span> Break points <span style="float: right;">+</span> Duration Points <span style="float: right;">= DP</span>																																																																																																																				
<table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <tr> <td style="width: 25%;"></td> <td style="width: 12.5%;"><b>&lt; 1</b></td> <td style="width: 12.5%;"><b>1,5</b></td> <td style="width: 12.5%;"><b>3</b></td> <td style="width: 12.5%;"><b>5</b></td> <td style="width: 12.5%;"><b>7</b></td> <td style="width: 12.5%;"><b>&gt; 8</b></td> <td></td> </tr> <tr> <td>Duration (h/shift)</td> <td>1</td> <td>1,5</td> <td>3</td> <td>5</td> <td>7</td> <td>10</td> <td>+</td> </tr> <tr> <td>Duration Points</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td rowspan="2">Work Organization</td> <td colspan="3">Breaks are possible at every time</td> <td colspan="2">Breaks are possible at given conditions</td> <td>Breaks lead to a stop of the process</td> <td rowspan="2">+</td> </tr> <tr> <td colspan="3">(Cycle time longer than 10 minutes)</td> <td colspan="2">(Cycle time between 1 and 10 minutes)</td> <td>(Cycle time shorter than 1 minute)</td> </tr> <tr> <td>Work Organization Points</td> <td colspan="3">0</td> <td colspan="2">1</td> <td>2</td> <td></td> </tr> <tr> <td rowspan="2">Breaks (≥ 8 min) (h/shift)</td> <td>0</td> <td>1</td> <td>2</td> <td>3</td> <td>4</td> <td>5</td> <td>6</td> <td>≥7</td> </tr> <tr> <td>3</td> <td>2</td> <td>1</td> <td>0</td> <td>-1</td> <td>-2</td> <td>-3</td> <td>-4</td> </tr> <tr> <td rowspan="2">Break points</td> <td colspan="2">cycle time ≤ 30 sec</td> <td colspan="2">cycle time &gt; 30 sec</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="2">0</td> <td colspan="2">-0,5</td> <td>-1</td> <td>-1,5</td> <td>-2</td> <td></td> </tr> <tr> <td>Duration Points</td> <td colspan="7"></td> <td>= DP</td> </tr> </table>																													<b>&lt; 1</b>	<b>1,5</b>	<b>3</b>	<b>5</b>	<b>7</b>	<b>&gt; 8</b>		Duration (h/shift)	1	1,5	3	5	7	10	+	Duration Points								Work Organization	Breaks are possible at every time			Breaks are possible at given conditions		Breaks lead to a stop of the process	+	(Cycle time longer than 10 minutes)			(Cycle time between 1 and 10 minutes)		(Cycle time shorter than 1 minute)	Work Organization Points	0			1		2		Breaks (≥ 8 min) (h/shift)	0	1	2	3	4	5	6	≥7	3	2	1	0	-1	-2	-3	-4	Break points	cycle time ≤ 30 sec		cycle time > 30 sec						0		-0,5		-1	-1,5	-2		Duration Points								= DP
	<b>&lt; 1</b>	<b>1,5</b>	<b>3</b>	<b>5</b>	<b>7</b>	<b>&gt; 8</b>																																																																																																														
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<b>Upper limb load in repetitive tasks</b>																																																																																																																				
20 ( (a) Force & Frequency & Grip + (b) Postures + (c) Additional factors ) x (d) Duration = Upper Limbs																																																																																																																				

## Ergonomic Assessment Worksheet V1.3.4

Basic Positions / Postures and movements of trunk and arms (per shift)											Postures															
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N)  Static postures: ≥ 4sec  High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min											Evaluation of static postures and/or high frequent movements of trunk/arms/legs										Asymmetry effects					
											Duration [sec/min] = $\frac{\text{duration of posture(s)} \times 60}{\text{cycle time}}$										Sum of lines	Trunk Rotation 1)		Lateral Bending 1)		Far Reach 2)
[%]		5	7.5	10	15	20	27	33	50	67	83	int	dur	int	dur	int	dur									
[sec/min]		3	4.5	6	9	12	16	20	30	40	50	Intensity x Duration		Intensity x Duration		Intensity x Duration										
[min/8h]		24	36	48	72	96	130	160	240	320	400															
<b>Standing (and walking)</b>																										
1		Standing & walking in alteration, standing with support	0	0	0	0	0.5	1	1	1	1.5	2														
2		Standing, no body support (for other restrict. see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13														
3		Bent forward (20-60°) with suitable support	2	3	5	7	9,5	12	18	23	32	40														
4		Strongly bent forward (>60°) with suitable support	3,3	5	8,5	12	17	21	30	38	51	63														
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63														
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100														
<b>Sitting</b>																										
7		Upright with back support slightly bent forward or backward	0	0	0	0	0	0,5	1	1,5	2															
8		Upright no back support (for other restrict. see Extra Points)	0	0	0,5	1	1,5	2	3	4	5,5	7														
9		Bent forward	0,7	1	1,5	2	3	4	6	8	11	13														
10		Elbow at / above shoulder level	2,7	4	7	10	13	16	23	30	40	50														
11		Hands above head level	4	6	10	14	20	25	35	45	60	75														
<b>Kneeling or crouching</b>																										
12		Upright	3,3	5	7	9	12	15	21	27	36	45	0													
13		Bent forward	4	6	10	14	20	25	35	45	60	75	7.33	3	1.76	3	1.13									
														5.28			3.39									
14		Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108	135														
<b>Lying or climbing</b>																										
15		(Lying on back, breast or side) arms above head	6	9	15	21	29	37	53	68	91	113														
16		Climbing	6,7	10	22	33	50	66																		
1)		0	1	3	5	2)		0	1	3	5	7.33	5.28		3.39											
Trunk		slightly <10°	medium 15°	strongly 25°	extreme >30°	Far Reach		close	60%	80%	arm stretched		$\Sigma$ (max.=15)		$\Sigma$ (max.=10)											
dur		0	1,5	2,5	3	dur		0	1	1,5	2		$\Sigma$ (max.=40)													
		never	4 sec	10 sec	13 sec			never	4 sec	10 sec	13 sec															
		0%	6%	15%	20%			0%	6%	15%	20%															
Attention: Max. duration of evaluation = duration of task or 100%!      Attention: correct evaluation, if duration of evaluation ≠ 60s																										
<b>Postures = <math>\Sigma</math> lines 1 - 16</b>			7.33 (a)				+		8.67 (b)				=		16											

### Ergonomic Assessment Worksheet V1.3.4

Action forces (per minute / shift)										Forces			
17		~40 N / twist Forces onto fingers (e.g. clips, plugs) < 15 twists									Intensity x time	Σ	
			$1.2 \times 3$										3
			[sec] 3 6 9 12 20 30 (%) 5 10 15 20 33 50										
			[N] 1.5 2 2.5 3 [kg] 0.15 0.2 0.25 0.3										
18		~10 N Forces onto arms / whole body forces open / close									Intensity x time	Σ	
			$0 \times 1.5$										0
			[sec] 3 6 9 12 20 30 (%) 5 10 15 20 33 50										
			[N] 1 2 3 4.5 6.5 10 [kg] 0.1 0.2 0.3 0.45 0.65 1.0										
<b>Finger forces F<sub>finger</sub> (neutral to gender)</b> P15 for planning & P40 for analysis  Data based on the "Anatomy specific force atlas" (Musch, Berg, Schaub, Gahrn, Ellegren 2009, weighted neutral to gender) Note: data are liable to change after the final completion of the force atlas project										Finger forces F <sub>finger</sub> (neutral to gender) Posture A1 (power grip, palm on 70%) F <sub>finger</sub> P15 P40 190 285			
<b>KN Upright</b> P15 P40 <b>KN Bent</b> P15 P40 <b>KN Above head</b> P15 P40 F <sub>finger</sub> P15 P40 115 155										Posture A2 (ball of the thumb) F <sub>finger</sub> P15 P40 100 140			
<b>SI Upright</b> P15 P40 <b>SI Bent</b> P15 P40 <b>SI Above head</b> P15 P40 F <sub>finger</sub> P15 P40 40 50										Posture B1 (thumb or thumb to 4 fingers) F <sub>finger</sub> P15 P40 55 70			
<b>SI Upright</b> P15 P40 <b>SI Bent</b> P15 P40 <b>SI Above head</b> P15 P40 F <sub>finger</sub> P15 P40 45 55										Posture B2 (index or wide pinch) F <sub>finger</sub> P15 P40 40 50			
<b>SI Upright</b> P15 P40 <b>SI Bent</b> P15 P40 <b>SI Above head</b> P15 P40 F <sub>finger</sub> P15 P40 45 55										Posture C (hook, palmar, strong pinch) F <sub>finger</sub> P15 P40 45 55			
Action forces = Σ lines 17 - 18										Attention: correct evaluation, if duration of evaluation ≠ 60s = 3			

Manual Material Handling (per shift)										Loads											
<b>Weights of loads [kg] for repositioning (lifting / lowering), carrying and holding as well as pushing and pulling</b>																					
Reposition, carrying & holding		Males		3	10	15	20	25	30	35	40	>40									
		Females		2	5	7	10	12	15	20	25	>25									
Load points		1		1.5	2	3	4	5.5	7	8.5	10	12.5									
Pushing and pulling		Males		Barrows		<50	75	100	150	200	250										
		Females		Barrows		<40	60	80	115	155	195										
		Males		Carriage, roller, trolleys		<50	75	100	150	250	350	550									
		Females		No fixed rollers		<40	60	80	115	195	270	425									
Load points		Males		Carts, roller tables, carriages, Fixed rollers		<50	75	150	250	350	500	800	1250								
		Females		Carriages, Fixed rollers		<40	60	115	195	270	385	460	615	960							
		Means of transport		0.5	1	1.5	2	3	4	5	6	8									
<b>Posture, position of load (select characteristic posture)</b>																					
Posture points		1		2		4		8													
		1		2		4		8													
<b>Working Conditions (pushing and pulling only)</b>																					
Conditions points		0		1		3		5		6		8									
		0		1		3		5		6		8									
<b>Frequency of load manipulations (#/shift), holding time (min) or travel distance (meter/shift)</b>																					
Frequency of repositionings / pushing & pulling short		5		25		120		350		750		1000		1500		2000		2500		3000	
		2.5		10		37		90		180		≥240									
		300		850		2500		6000		12000		≥16000									
Distance (carrying, pushing & pulling long) [m]		3		2		4		6		8		10		11		13		14		15	
# duration or distance points		3		2		4		6		8		10		11		13		14		15	
<b>Manual Material Handling (result)</b>																					
Handling = Σ line 19		Repositioning		Holding		Carrying		Pushing & pulling short		Pushing & pulling long											
		X		X		X		X		X											
1) Maximal cumulative time points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15																					

## Two Door



### Ergonomic Assessment Worksheet V1.3.4

Plant	Gender of operator m <input type="checkbox"/> f <input type="checkbox"/>	Body height
Line	MTM Analysis	Analyst
Task / Workplace <i>Two Doors</i>	Task duration [sec]	Date

**Result of overall evaluation:** Calculate the total score of the whole body sections and compare it to the upper limbs score. The overall result is determined by the higher value but interpretation should also take into account the second value.

<input checked="" type="checkbox"/> Green <input type="checkbox"/> Yellow <input type="checkbox"/> Red	<b>Whole Body</b>	=	<b>Postures</b>	+	<b>Forces</b>	+	<b>Loads</b>	+	<b>Extra</b>	<b>Upper Limbs</b>
	19	=	10	+	3	+	n/a	+	n/a	8

<b>EAWs evaluation</b>	0-25 Points	Green	Low risk: recommended; no action is needed
	>25-50 Points	Yellow	Possible risk: not recommended; redesign if possible, otherwise take other measures to control the risk
	>50 Points	Red	High risk: to be avoided; action to lower the risk is necessary



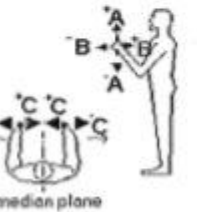
Extra points "Whole body" (per minute / shift)					Extra points		
0a	Adverse effects by working on moving objects	0 none	3 middle	8 strong	15 very strong	Intensity	
0b	Accessibility (e.g. entering motor or passenger compartment)	0 good	2 complicated	5 poor	10 very poor	Status	
0c	Countershocks, impulses, vibrations 	0 light	1 visible	2 heavy	5 very heavy	Intensity x frequency	
		0 [n] 1-2	2,5 4-5	4 8-10	6 18-20		8 >20
0d	Joint position (especially wrist) 	0 neutral	1 - 1/3 max	3 - 2/3 max	5 maximal	Intensity x duration or frequency	
		0 [sec] 3	2 10	2,5 20	4 40		6 80
		0 [n] 1	8 8	11 11	16 16		20 20
0e	Other physical work load (please describe in detail)	0 none	5 middle	10 strong	15 very strong	Intensity	
<b>Extra = Σ lines 0a - 0e</b>		Attention: Max. score = 40 (line 0c, 0d); Max. score = 15 (line 0a, 0e); Max. score = 10 (line 0b)			Attention: correct evaluation, if duration of evaluation ≠ 60s		
Lines 0a-0e mainly relate to the Automotive industry, for other sectors additional elements may be necessary. For details see the EAWs manual.							

For scoring of repetitive tasks only:			Comments / proposals for improvements
Description	Formula	Result	
Real shift duration [min]			
Lunch break [min]	-		
Other official pauses [min]	-		
Non repetitive tasks (i.e. cleaning, supplies, etc) [min]	-		
No) duration of repetitive task/s (a) [min]	=		
No. of real units (or cycles) (b)			
Net cycle time [sec]	(a/b x 60) =		
Observed cycle time [sec]			

## Ergonomic Assessment Worksheet V1.3.4

Basic Positions / Postures and movements of trunk and arms (per shift)											Postures																																																													
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N)  Static postures: ≥ 4sec  High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm flittings (> 60°) ≥ 10/min											Evaluation of static postures and/or high frequent movements of trunk/arms/legs										Asymmetry effects																																																			
											Duration (sec/min) = $\frac{\text{duration of posture(s)} \times 60}{\text{cycle time}}$										Sum of times	Trunk Rotation 1)		Lateral Bending 1)		Far Reach 2)																																														
											[%]	5	7.5	10	15	20	27	33	50	67		83	int	dur	int	dur	int	dur																																												
[sec/min]	3	4.5	6	9	12	16	20	30	40	50	0.5	0.3	0.5	0.3	0.5	0.2																																																								
[min/8h]	24	36	48	72	96	130	160	240	320	400	Intensity x Duration		Intensity x Duration		Intensity x Duration																																																									
<b>Standing (and walking)</b>																																																																								
1		Standing & walking in alteration, standing with support	0	0	0	0	0.5	1	1	1	1.5	2																																																												
2		Standing, no body support (for other restrict. see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13																																																												
3		Bent forward (20-60°) with suitable support	2	3	5	7	9,5	12	18	23	32	40																																																												
4		Strongly bent forward (>60°) with suitable support	3,3	5	8,5	12	17	21	30	38	51	63																																																												
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63																																																												
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100																																																												
<b>Sitting</b>																																																																								
7		Upright with back support slightly bent forward or backward	0	0	0	0	0	0,5	1	1,5	2																																																													
8		Upright no back support (for other restrict. see Extra Points)	0	0	0,5	1	1,5	2	3	4	5,5	7																																																												
9		Bent forward	0,7	1	1,5	2	3	4	6	8	11	13																																																												
10		Elbow at / above shoulder level	2,7	4	7	10	13	16	23	30	40	50																																																												
11		Hands above head level	4	6	10	14	20	25	35	45	60	75																																																												
<b>Kneeling or crouching</b>																																																																								
12		Upright	3,3	5	7	9	12	15	21	27	36	45	0																																																											
13		Bent forward	4	6	10	14	20	25	35	45	60	75	7.33	1	3	1,76	3	1,13																																																						
														5.28	3	3,39																																																								
14		Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108	135																																																												
<b>Lying or climbing</b>																																																																								
15		(Lying on back, breast or side) arms above head	6	9	15	21	29	37	53	68	91	113																																																												
16		Climbing	6,7	10	22	33	50	66																																																																
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">Trunk int</td> <td>0</td><td>1</td><td>3</td><td>5</td> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">Far Reach int</td> <td>0</td><td>1</td><td>3</td><td>5</td> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">Σ</td> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">7.33</td> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">Σ (max = 15)</td> <td>5.28</td> <td>3.39</td> </tr> <tr> <td>slightly ≤10°</td><td>medium 15°</td><td>strongly 25°</td><td>extreme ≥30°</td> <td>close</td><td>10%</td><td>80%</td><td>arm stretched</td> <td>Σ (max = 15)</td> <td>Σ (max = 10)</td> </tr> <tr> <td>0</td><td>1,5</td><td>2,5</td><td>3</td> <td>0</td><td>1</td><td>1,5</td><td>2</td> <td>Σ (max = 40)</td> <td></td> </tr> <tr> <td>never</td><td>4 sec</td><td>10 sec</td><td>13 sec</td> <td>never</td><td>4 sec</td><td>10 sec</td><td>13 sec</td> <td></td><td></td> </tr> <tr> <td>0%</td><td>6%</td><td>15%</td><td>20%</td> <td>0%</td><td>6%</td><td>15%</td><td>20%</td> <td>(a)</td><td>8.67</td><td>(b)</td> </tr> </table>																	Trunk int	0	1	3	5	Far Reach int	0	1	3	5	Σ	7.33	Σ (max = 15)	5.28	3.39	slightly ≤10°	medium 15°	strongly 25°	extreme ≥30°	close	10%	80%	arm stretched	Σ (max = 15)	Σ (max = 10)	0	1,5	2,5	3	0	1	1,5	2	Σ (max = 40)		never	4 sec	10 sec	13 sec	never	4 sec	10 sec	13 sec			0%	6%	15%	20%	0%	6%	15%	20%	(a)	8.67	(b)
Trunk int	0	1	3	5	Far Reach int	0	1	3	5	Σ	7.33	Σ (max = 15)	5.28	3.39																																																										
	slightly ≤10°	medium 15°	strongly 25°	extreme ≥30°		close	10%	80%	arm stretched				Σ (max = 15)	Σ (max = 10)																																																										
	0	1,5	2,5	3		0	1	1,5	2				Σ (max = 40)																																																											
	never	4 sec	10 sec	13 sec		never	4 sec	10 sec	13 sec																																																															
0%	6%	15%	20%	0%	6%	15%	20%	(a)	8.67	(b)																																																														
Attention: Max. duration of evaluation = duration of task or 100%! Attention: correct evaluation, if duration of evaluation ≠ 60s																																																																								
<b>Postures = Σ lines 1 - 16</b>			7.33	(a)	+	8.67	(b)	=	16																																																															

## Ergonomic Assessment Worksheet V1.3.4




Action forces (per minute / shift)										Forces			
17		$\sim 40N$ / twist Forces onto fingers (e.g. clips, plugs) $< 15$ twists	0	1	1.5	2	3.5	7	Intensity x time $1.2 \times 2.5$	$\Sigma$  3			
			-1/6 F <sub>max</sub>	-1/3 F <sub>max</sub>	-1/2 F <sub>max</sub>	-2/3 F <sub>max</sub>	F <sub>max</sub>						
			[sec]	3	6	9	12	20			30		
			[%]	5	10	15	20	33			50		
18		$\sim 5N$ Forces onto arms / whole body forces open / close (12 times)	0	1	1.5	2	4	8.5	Intensity x time $0 \times 2.33$	$\Sigma$  0			
			-1/6 F <sub>max</sub>	-1/3 F <sub>max</sub>	-1/2 F <sub>max</sub>	-2/3 F <sub>max</sub>	F <sub>max</sub>						
			[sec]	3	6	9	12	20			30		
			[%]	5	10	15	20	33			50		
Forces F <sub>max</sub> onto arms / whole body forces (neutral to gender) P15 for planning & P40 for analysis			ST Upright	P15	P40	ST Bent	P15	P40	ST Above head	P15	P40	Finger forces F <sub>max</sub> (neutral to gender) Posture A1 (power grip, pliers, etc 70%)	
			KH Upright	P15	P40	KH Bent	P15	P40	KH Above head	P15	P40		
 median plane Data based on the "Assessing specific force areas" (Hanus, Deng, Schmitt, Sliwa, Elgen 2008), adapted relative to gender Score data are neither to change after the final completion of the force area project			A	245	315	A	210	285	A	230	280	Posture A2 (ball of the thumb)	
			B	280	325	B	200	240	B	265	320		
			C	170	210	C	285	280	C	180	200	Posture B1 (thumb or thumb to 4 fingers)	
			A	245	315	A	285	300	A	255	310		
			B	130	185	B	145	200	B	105	140	Posture B2 (index or wide pinch)	
			C	110	165	C	90	135	C	100	140		
			A	210	270	A	180	245	A	225	275	Posture C (hook, palmar, strong pinch)	
			B	225	280	B	190	225	B	265	320		
			C	215	290	C	220	320	C	210	270	Posture D (hook, palmar, strong pinch)	
			A	240	325	A	220	290	A	220	275		
			B	240	325	B	220	290	B	220	275	Posture E (hook, palmar, strong pinch)	
			C	145	195	C	140	190	C	130	180		
			A	205	265	A	190	250	A	215	255	Posture F (hook, palmar, strong pinch)	
			B	245	285	B	195	245	B	250	295		
			C	215	260	C	245	295	C	195	240	Posture G (hook, palmar, strong pinch)	
			A	205	250	A	215	275	A	210	240		
			B	205	250	B	215	275	B	210	240	Posture H (hook, palmar, strong pinch)	
			C	120	165	C	130	175	C	100	130		
			A	110	155	A	100	135	A	100	135	Posture I (hook, palmar, strong pinch)	
			B	110	155	B	100	135	B	100	135		
Action forces = $\Sigma$ lines 17 - 18										Attention: correct evaluation, if duration of evaluation $\neq$ 60s		=	3

Manual Material Handling (per shift)										Loads			
Weights of loads [kg] for repositioning (lifting / lowering), carrying and holding as well as pushing and pulling													
+	Reposition, carrying & holding	Males	5	10	15	20	25	30	35	40	$\geq 40$		
		Females	2	5	7	10	12	15	20	25	$\geq 25$		
+	Load points	Means of transport											
		1	1.5	2	3	4	5.5	7	8.5	25			
+	Pushing and pulling	Males	Barrows			<50	75	100	150	200	250		
		Females	Carriage, roller, trolleys			<40	60	80	115	155	195		
+	Load points	Males	No fixed rollers			<50	75	100	150	250	350	550	
		Females	Carts, roller tables, carriages. Fixed rollers			<40	60	80	115	195	270	425	
+	Load points	Males	Means of transport			<50	75	150	250	350	500	800	1250
		Females	Means of transport			<40	60	115	195	270	385	460	615
Posture, position of load (select characteristic posture)													
+	Posture points	1	2	4	8								
		trunk upright and / or not twisted load at the body little trunk bending or twisting; load at or close to the body bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level bending trunk far forward and twisting; load far from the body; limited postural stability while standing; crouching or kneeling											
Working Conditions (pushing and pulling only)													
(*)	Conditions points	0	1	3	5	6	8	very high rolling resistance					
		very low rolling resistance trolley pushing / pulling on (very) slick floor rough floor and above small gaps / edges on structured sheet metal, into / out of a track trolleys have to be leaved off when starting, strongly damaged floor											
Frequency of load manipulations (#/shift), holding time [min] or travel distance [meter/shift]													
x	Frequency of repositionings / pushing & pulling short	5	25	120	350	750	1000	1500	2000	2500	3000		
	Duration (holding time) [min]	2.5	10	37	90	180	$\geq 240$						
	Distance (carrying, pushing & pulling long) [m]	300	650	2500	6000	12000	$\geq 16000$						
	# duration or distance points	1	2	4	6	8	10	11	13	14	15		
Manual Material Handling (result)													
19	Handling = $\Sigma$ line 19	1) Maximal cumulative time points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15										=	

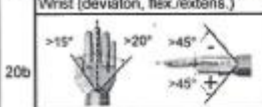
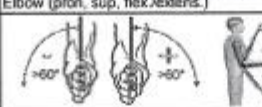
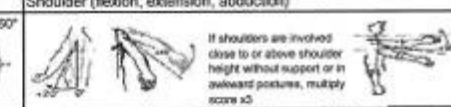
## Ergonomic Assessment Worksheet V1.3.4

### Upper limb load in repetitive tasks Upper Limbs

**Force & Frequency & Grip (FFG)** Basis: number of real actions per minute or percent static actions (analyze only the most loaded limb)

			Force & Duration	Grip	Percentage of time involved	Force & Duration (Force x Duration) + (Grip x Percentage of time involved) Very long lasting static actions: almost 75% Long lasting static actions: almost 50% Substantial amount of static actions: ~35% Considerable amount of static actions: ~15% Low amount of static actions: ~10% Very low amount of static actions: < 5% Good grasping conditions Moderate grasping conditions Poor grasping conditions Static Slow arm movements, few short interruptions Arm movements not too fast, short interrupt. Normal arm movements, but short or occasional and irregular interruptions Fast arm movements, occasional and irregular short pauses Continuous arm movements, lack of interruptions make difficult to keep pace Very high frequency, absolutely no interruptions None															Calc Stat																Calc Dyn
Force [N]	FFS	GS	%	FFGp	245	30	20	10	5	3	0	2	4	2	10	15	20	25	30	35	≥40	FFG	%	FFGp													
0 - 5					1	1	0	0	0	0	abc				0	0	0	1	2	3	4	7															
> 5 - 20	3	2	100	5	4	2	1	1	0	0	ab	bc			0	0	1	2	3	4	6	9															
> 20 - 35					7	5	3	2	1	1	ab	b	c		0	1	2	3	4	6	8	12															
> 35 - 90					11	8	5	3	2	1	a	b	b		1	2	3	5	7	9	12	18	3	100	3												
> 90 - 135					16	11	7	4	3	2	a	ab	b		2	3	5	7	9	12	15	24															
> 135 - 225					21	14	10	6	4	3	a	a	b		4	5	8	8	11	14	20	32															
> 225 - 300					28	18	12	8	5	4	a	a	b		5	6	7	9	12	16	26	40															
20a	FFGS = ∑ FFGp			100%	5	FFG = FFGS + FFGD										8	FFGD = ∑ FFGp					NDA	3														

### Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)

	Wrist (deviation, flex./extens.)	Elbow (pron. sup, flex./extens.)	Shoulder (flexion, extension, abduction)
20b			
Posture points	10% 0	25% 0.5	33% 1
	50% 2	65% 3	85% 4
	PP		

**Additional factors**

Gloves inadequate (which interfere with the handling ability required) are used for over half the time	2	<input type="checkbox"/>
Working gestures required imply a countershock. Frequency of 2 time per minute or more (i.e.: hammering over hard surface)	2	<input type="checkbox"/>
Working gestures imply a countershock (using the hand as a tool) with freq. of 10 time per hour or more	2	<input type="checkbox"/>
Exposure to cold or refrigeration (less than 0 degree) for over half the time	2	<input type="checkbox"/>
Vibrating tools are used for 1/3 of the time or more	2	<input type="checkbox"/>
Tools with a very high level of vibrations	4	<input type="checkbox"/>
Tools employed cause compressions of the skin (rednesses, callosities, blebs, etc.)	2	<input type="checkbox"/>
Precision tasks are carried out for over half the time (tasks over areas smaller than 2-3 mm)	2	<input type="checkbox"/>
More than one additional factor is present at the same time and overall occupy the whole of the time	3	<input type="checkbox"/>
<b>Additional points (choose the highest value)</b>	=	AF

**Repetitive tasks duration**

Duration [h/shift]	$< 1$	1.5	3	5	7	> 8	
Duration Points	1	1.5	3	5	7	10	+
Work Organization	Breaks are possible at every time		Breaks are possible at given conditions		Breaks lead to a stop of the process		+
Work Organization Points	0		1		2		+
Breaks (≥ 8 min) [h/shift]	0	1	2	3	4	5	+
Break points	cycle time ≤ 30 sec	3	2	1	0	-1	-2
	cycle time > 30 sec	0	-0.5	-1	-1.5	-2	+
Duration Points	=						DP

**Upper limb load in repetitive tasks**

20	(a) Force & Frequency & Grip	(b) Postures	(c) Additional factors	(d) Duration	Upper Limbs
	FFG +	PP +	AF	X	DP =





# Four Bar

Ergonomic Assessment Worksheet V1.3.4		
Plant	Gender of operator <input type="checkbox"/> m <input type="checkbox"/> f	Body height
Line	MTM Analysis	Analyst
Task / Workplace <i>Four Bars</i>	Task duration (sec)	Date

**Result of overall evaluation:** Calculate the total score of the whole body sections and compare it to the upper limbs score. The overall result is determined by the higher value but interpretation should also take into account the second value.

<input checked="" type="checkbox"/> Green	<b>Whole Body</b>	=	<b>Postures</b>	+	<b>Forces</b>	+	<b>Loads</b>	+	<b>Extra</b>	<b>Upper Limbs</b>
<input type="checkbox"/> Yellow	17.73	=	11.73	+	3	+	n/a	+	n/a	4
<input type="checkbox"/> Red										

EAWs evaluation	0-25 Points	Green	Low risk; recommended; no action is needed
	>25-50 Points	Yellow	Possible risk; not recommended; redesign if possible, otherwise take other measures to control the risk
	>50 Points	Red	High risk; to be avoided; action to lower the risk is necessary

Extra points "Whole body" (per minute / shift)						Extra points		
0a	Adverse effects by working on moving objects	0 none	3 middle	8 strong	15 very strong	Intensity		
0b	Accessibility (e.g. entering motor or passenger compartment)	0 good	2 complicated	5 poor	10 very poor	Status		
0c	Countershocks, impulses, vibrations 	0	1	2	5	Intensity x frequency		
		light	visible	heavy	very heavy			
0d	Joint position (especially wrist) 	0	1	3	5	Intensity x duration or frequency		
		neutral	- 1/3 max	- 2/3 max	maximal			
		0	2	2,5	4		6	8
		[sec]	3	10	20		40	60
	[n]	1	8	11	16	20		
	[%]	5	17	33	67	100		
0e	Other physical work load (please describe in detail)	0 none	5 middle	10 strong	15 very strong	Intensity		
<b>Extra = Σ lines 0a - 0e</b>		Attention: Max. score = 40 (line 0c, 0d); Max. score = 15 (line 0a, 0e); Max. score = 10 (line 0b)		Attention: correct evaluation, if duration of evaluation ≠ 60s		=		

Lines 0a-b mainly relate to the Automotive Industry; for other sectors additional elements may be necessary. For details see the EAWs manual.



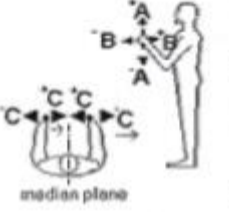
For scoring of repetitive tasks only:		
Description	Formula	Result
Real shift duration [min]		
Lunch break [min]	-	
Other official pauses [min]	-	
Non repetitive tasks (i.e. cleaning, supplies, etc) [min]	-	
Net duration of repetitive tasks (a) [min]	=	
No. of real units (or cycles) (b)		
Net cycle time [sec]	(a) × 60 =	
Observed cycle time [sec]		






Comments / proposals for improvements

## Ergonomic Assessment Worksheet V1.3.4

Basic Positions / Postures and movements of trunk and arms (per shift)											Postures																
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N)  Static postures: ≥ 4sec  High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min											Evaluation of static postures and/or high frequent movements of trunk/arms/legs											Asymmetry effects					
											Duration [sec/min] = $\frac{\text{duration of posture(s)} \times 60}{\text{cycle time}}$											Sum of lines					
											Trunk Rotation 1)		Lateral Bending 1)		Far Reach 2)												
											int dur		int dur		int dur												
											0-5 0-3		0-5 0-3		0-5 0-2												
											Intensity x Duration		Intensity x Duration		Intensity x Duration												
<b>Standing (and walking)</b>																											
1		Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2															
2		Standing, no body support (for other restrict. see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13	0														
3		Bent forward (20-60°) with suitable support	2	3	5	7	9,5	12	18	23	32	40															
4		Strongly bent forward (>60°) with suitable support	3,3	5	8,5	12	17	21	30	38	51	63															
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63															
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100															
<b>Sitting</b>																											
7		Upright with back support slightly bent forward or backward	0	0	0	0	0	0,5	1	1,5	2																
8		Upright no back support (for other restrict. see Extra Points)	0	0	0,5	1	1,5	2	3	4	5,5	7															
9		Bent forward	0,7	1	1,5	2	3	4	6	8	11	13	1,17	5   1,76 8,8	1   1,76 1,76												
10		Elbow at / above shoulder level	2,7	4	7	10	13	16	23	30	40	50															
11		Hands above head level	4	6	10	14	20	25	35	45	60	75															
<b>Kneeling or crouching</b>																											
12		Upright	3,3	5	7	9	12	15	21	27	36	45															
13		Bent forward	4	6	10	14	20	25	35	45	60	75															
14		Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108	135															
<b>Lying or climbing</b>																											
15		(Lying on back, breast or side) arms above head	6	9	15	21	29	37	53	68	91	113															
16		Climbing	6,7	10	22	33	50	66																			
1)		0 1 3 5											Σ		8,8	1,76											
		slightly ≤10°	medium 15°	strongly 25°	extreme ≥30°											Σ		(max = 15)	(max = 15)	(max = 10)							
		0	1,5	2,5	3											Σ (max. = 40)											
		never	4 sec	10 sec	13 sec																						
		0%	6%	15%	20%													10,56									
												(a)				(b)											
2)		0 1 3 5											Σ														
		close	60%	80%	arm stretched											Σ											
		0	1	1,5	2																						
		never	4 sec	10 sec	13 sec																						
		0%	6%	15%	20%																						
												(a)				(b)											
Attention: Max. duration of evaluation = duration of task or 100%!			Attention: correct evaluation, if duration of evaluation ≠ 60s																								
Postures = Σ lines 1 - 16			1,17 (a)				+				10,56 (b)				=				11,73								

## Ergonomic Assessment Worksheet V1.3.4

Action forces (per minute / shift)										Forces					
17		<p>~ 40 N Twist Forces onto fingers (e.g. clips, plugs) ~ 15 twists</p>	0	7	15	25	50	Intensity x time $1.2 \times 2.5$	Σ	3					
			-1/6 F <sub>max</sub>	-1/3 F <sub>max</sub>	-1/2 F <sub>max</sub>	-2/3 F <sub>max</sub>	F <sub>max</sub>								
			0	1	1.5	2	3.5				7				
			[sec]	3	6	9	12				20	30			
18		<p>~ 8 N/hand Forces onto arms / whole body forces open and close</p>	0	6	15	25	50	Intensity x time Left $0 \times 1.5$ Right $0 \times 1.5$	Σ	0					
			-1/6 F <sub>max</sub>	-1/3 F <sub>max</sub>	-1/2 F <sub>max</sub>	-2/3 F <sub>max</sub>	F <sub>max</sub>								
			0	1	1.5	2	4				6.5				
			[n]	4	10	15	20				33	50			
 <p>median plane</p> <p>Data based on the "Assembly specific force atlas" (Winkel, Berg, Schmitt, Glitsch, Etzinger 2005), weighted neutral to gender</p> <p>Score data are rather to change after final completion of the force atlas project</p>		ST Upright		P15	P40	ST Bent		P15	P40	ST Above head		P15	P40	Finger forces F <sub>max</sub> (neutral to gender)	
		A	245	315	A	210	285	A	230	290	Posture A1 (power grip, plane on 70%)		F <sub>max</sub>	P15	P40
		B	260	325	B	200	240	B	265	320	Posture A2 (ball of the thumb)		F <sub>max</sub>	P15	P40
		C	170	210	C	205	260	C	255	310	Posture B1 (thumb or thumb to 4 fingers)		F <sub>max</sub>	P15	P40
		D	245	315	D	285	390	D	285	390	Posture B2 (index or side pinch)		F <sub>max</sub>	P15	P40
		E	110	165	E	145	200	E	105	140	Posture C (hook, palmar, strong pinch)		F <sub>max</sub>	P15	P40
		KN Upright		P15	P40	KN Bent		P15	P40	KN Above head		P15	P40	F <sub>max</sub>	
		A	210	270	A	180	245	A	225	275	Posture A1 (power grip, plane on 70%)		F <sub>max</sub>	P15	P40
		B	225	290	B	190	225	B	265	320	Posture B1 (thumb or thumb to 4 fingers)		F <sub>max</sub>	P15	P40
		C	215	290	C	220	320	C	210	270	Posture B2 (index or side pinch)		F <sub>max</sub>	P15	P40
		D	240	325	D	220	290	D	220	275	Posture C (hook, palmar, strong pinch)		F <sub>max</sub>	P15	P40
		E	145	195	E	140	190	E	130	180	Posture A2 (ball of the thumb)		F <sub>max</sub>	P15	P40
F	115	160	F	105	135	F	130	180	Posture B1 (thumb or thumb to 4 fingers)		F <sub>max</sub>	P15	P40		
SI Upright		P15	P40	SI Bent		P15	P40	SI Above head		P15	P40	F <sub>max</sub>			
A	205	265	A	190	250	A	215	255	Posture A1 (power grip, plane on 70%)		F <sub>max</sub>	P15	P40		
B	245	305	B	195	240	B	260	295	Posture B1 (thumb or thumb to 4 fingers)		F <sub>max</sub>	P15	P40		
C	215	290	C	245	295	C	195	240	Posture B2 (index or side pinch)		F <sub>max</sub>	P15	P40		
D	205	250	D	215	275	D	210	240	Posture C (hook, palmar, strong pinch)		F <sub>max</sub>	P15	P40		
E	120	165	E	130	175	E	100	130	Posture A2 (ball of the thumb)		F <sub>max</sub>	P15	P40		
F	110	155	F	100	135	F	100	135	Posture B1 (thumb or thumb to 4 fingers)		F <sub>max</sub>	P15	P40		
Action forces = Σ lines 17 - 18										= 3					




Manual Material Handling (per shift)										Loads		
Weights of loads [kg] for repositioning (lifting / lowering), carrying and holding as well as pushing and pulling												
*	Reposition, carrying & holding	Males	3	10	15	20	25	30	35	40	>40	
		Females	2	5	7	10	12	15	20	25	>25	
*	Pushing and pulling	Males	1	1.5	2	3	4	5.5	7	8.5	25	
		Females	1	1.5	2	3	4	5.5	7	8.5	25	
Load points		Barrows		<50	75	100	150	200	250			
Load points		Carriage, roller, trolleys		<40	60	80	115	155	195			
Load points		No fixed rollers		<50	75	100	150	250	350	550		
Load points		Carts, roller tables,		<40	60	80	115	195	270	425		
Load points		carriages, Fixed rollers		<50	75	150	250	350	500	600	800	1250
Load points		Means of transport		<40	60	115	195	270	385	480	615	960
Load points		Means of transport		0.5	1	1.5	2	3	4	5	6	8
Posture, position of load (select characteristic posture)												
*	trunk upright and / or not twisted load at the body											
		little trunk bending or twisting; load at or close to the body		bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level		bending trunk far forward and twisting; load far from the body; limited postural stability while standing, crouching or kneeling		bending trunk far forward and twisting; load far from the body; limited postural stability while standing, crouching or kneeling		bending trunk far forward and twisting; load far from the body; limited postural stability while standing, crouching or kneeling		
Posture points		1	2	3	4	5	6	7	8			
Working Conditions (pushing and pulling only)												
(+)	very low rolling resistance	trolley pushing / pulling on (very) slick floor		rough floor and above small gaps / edges		on structured sheet metal, into / out of a track		trolleys have to be forced off when starting, strongly damaged floor		very high rolling resistance		
		Conditions points		1	3	5	6	7	8			
Frequency of load manipulations (#/shift), holding time [min] or travel distance [meter/shift]												
x	Frequency of repositionings / pushing & pulling short											
	Duration (holding time) [min]											
	Distance (carrying, pushing & pulling long) [m]											
# duration or distance points		1	2	4	6	8	10	11	13	14	15	
Manual Material Handling (result)												
19	(Load + posture + condition points) x (# duration or distance points)											
	Repositioning	1	2	3	4	5	6	7	8	9	10	
Handling = Σ line 19												
1) Maximal cumulative time points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15												

## Ergonomic Assessment Worksheet V1.3.4

### Upper limb load in repetitive tasks Upper Limbs

**Force & Frequency & Grip (FFG)**

Basis: number of real actions per minute or percent static actions (analyze only the most loaded task)

Force & Duration (Grip + Percentage of time involved)

Static actions (sec/min): Very long lasting static actions, almost 15%; Long lasting static actions, almost 50%; Substantial amount of static actions - 30%; Considerable amount of static actions - 15%; Low amount of static actions - 10%; Very low amount of static actions - 5%; Good gripping conditions; Moderate gripping conditions; Poor gripping conditions; Grip strength; Slow arm movements, few short interruptions; Arm movements not too fast, short intervals; Rapid arm movements, but slow or occasional and irregular interruptions; Frear arm movements, occasional and regular short pauses; Continuous arm movements. Lack of interruptions make difficulties to keep pace with high frequencies, absolutely no interruptions; Others.

Force & Frequency + Grip

Percentage of time involved


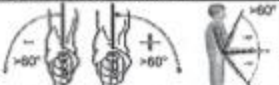
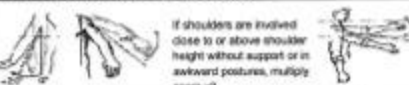
(Force & Frequency) + Grip + percentage

Force [N]	Calc Stat			Static actions (sec/min)										Grip				Dynamic actions (real actions/min)										Calc Dyn		
	FFG	GS	%	FFGp	≥45	30	20	10	5	3	0	2	4	10	15	20	25	30	35	≥40	FFG	%	FFGp							
0 - 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7									
> 5 - 20	1	0	100	1	4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9									
> 20 - 35					7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12									
> 35 - 60					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18	3	100	3						
> 60 - 135					18	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24									
> 135 - 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32									
> 225 - 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40									

20a  $FFGS = \sum FFGp$  100% |  $FFG = FFGS + FFGD$  4 FFG  $FFGD = \sum FFGp$  %SDA 3

#### Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)

Wrist (deviation, flex./extens.)    Elbow (pron, sup, flex./extens.)    Shoulder (flexion, extension, abduction)

Posture points: 10%, 25%, 33%, 50%, 65%, 85%

0, 0.5, 1, 2, 3, 4, PP

#### Additional factors

Gloves inadequate (which interfere with the handling ability required) are used for over half the time 2 
  
 Working gestures required imply a countershock. Frequency of 2 time per minute or more (i.e.: hammering over hard surface) 2 
  
 Working gestures imply a countershock (using the hand as a tool) with freq. of 10 time per hour or more 2 
  
 Exposure to cold or refrigeration (less than 0 degree) for over half the time 2 
  
 Vibrating tools are used for 1/3 of the time or more 2 
  
 Tools with a very high level of vibrations 4 
  
 Tools employed cause compressions of the skin (rednesses, callouses, blebs, etc.) 2 
  
 Precision tasks are carried out for over half the time (tasks over areas smaller than 2-3 mm) 2 
  
 More than one additional factor is present at the same time and overall occupy the whole of the time 3

Additional points (choose the highest value) = AF

#### Repetitive tasks duration



Duration [h/shift]	< 1	1.5	3	5	7	> 8		
Duration Points	1	1.5	3	5	7	10	+	
Work Organization	Breaks are possible at every time		Breaks are possible at given conditions		Breaks lead to a stop of the process		+	
	(Cycle time longer than 10 minutes)		(Cycle time between 1 and 10 minutes)		(Cycle time shorter than 1 minute)			
Work Organization Points	0		1		2			
Breaks (≥ 8 min) [h/shift]	0	1	2	3	4	5	6	≥7
Break points	cycle time ≤ 30 sec		-		-		-	
	3	2	1	0	-1	-2	-3	-4
Duration Points	cycle time > 30 sec		-		-		-	
	0		-0.5		-1		-1.5	

= DP

#### Upper limb load in repetitive tasks

20 ( (a) Force & Frequency & Grip + (b) Postures + (c) Additional factors ) x (d) Duration = Upper Limbs

## Double Slider-Crank

Ergonomic Assessment Worksheet V1.3.4													
Plant	Gender of operator <input type="checkbox"/> m <input type="checkbox"/> f		Body height										
Line	MTM Analysis			Analyst									
Task / Workplace <i>Double Slider-Crank</i>	Task duration [sec]		Date										
<b>Result of overall evaluation:</b> Calculate the total score of the whole body sections and compare it to the upper limbs score. The overall result is determined by the higher value but interpretation should also take into account the second value.													
<input checked="" type="checkbox"/> Green <input type="checkbox"/> Yellow <input type="checkbox"/> Red	Whole Body	=	Postures	+	Forces	+	Loads	+	Extra	+	Upper Limbs		
	14.73	=	11.73	+	3	+	n/a	+	n/a	+	4		
EAWs evaluation	0-25 Points	Green	Low risk: recommended; no action is needed										
	>25-50 Points	Yellow	Possible risk: not recommended; redesign if possible, otherwise take other measures to control the risk										
	>50 Points	Red	High risk: to be avoided; action to lower the risk is necessary										
Extra points "Whole body" (per minute / shift)										Extra points			
0a	Adverse effects by working on moving objects	0	3	8	15	Intensity							
		none	middle	strong	very strong								
0b	Accessibility (e.g. entering motor or passenger compartment)	0	2	5	10	Status							
		good	complicated	poor	very poor								
0c	Countershocks, impulses, vibrations 	0	1	2	5	Intensity x frequency							
			light	visible	heavy	very heavy							
		0	1	2.5	4	6	8						
		[n]	1 - 2	4 - 5	8 - 10	18 - 20	> 20						
0d	Joint position (especially wrist) 	0	1	3	5	Intensity x duration or frequency							
			neutral	- 1/3 max	- 2/3 max	maximal							
		0	2	2.5	4	6	8						
		[sec]	3	10	20	40	60						
		[n]	1	8	11	16	20						
		[%]	5	17	33	67	100						
0e	Other physical work load (please describe in detail)	0	5	10	15	Intensity							
		none	middle	strong	very strong								
<b>Extra = ∑ lines 0a - 0e</b>		Attention: Max. score = 40 (line 0c, 0d); Max. score = 15 (line 0e, 0e); Max. score = 10 (line 0b)			Attention: correct evaluation, f duration of evaluation ≠ 60s								
Lines 0a-e mainly relate to the Automotive Industry, for other sectors additional elements may be necessary. For details see the EAWs manual.													

For scoring of repetitive tasks only:			Comments / proposals for improvements
Description	Formula	Result	
Real shift duration [min]			
Lunch break [min]	-		
Other official pauses [min]	-		
Non repetitive tasks (i.e. cleaning, supplies, etc) [min]	-		
Net duration of repetitive task/s (a) [min]	=		
No. of real units (or cycles) (b)			
Net cycle time [sec]	(a/b) × 60 =		
Observed cycle time [sec]			

## Ergonomic Assessment Worksheet V1.3.4

Basic Positions / Postures and movements of trunk and arms (per shift)											Postures															
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N)  Static postures: ≥ 4sec  High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min											Evaluation of static postures and/or high frequent movements of trunk/arms/legs										Asymmetry effects					
											$\text{Duration [sec/min]} = \frac{\text{duration of posture(s)} \times 60}{\text{cycle time}}$										Sum of lines	Trunk Rotation 1)		Lateral Bending 1)		Far Reach 2)
[%]	5	7,5	10	15	20	27	33	50	67	83	int	dur	int	dur	int	dur										
[sec/min]	3	4,5	6	9	12	16	20	30	40	50	0-5	0-3	0-5	0-3	0-5	0-2										
[min/8h]	24	36	48	72	96	130	160	240	320	400	Intensity x Duration		Intensity x Duration		Intensity x Duration											
<b>Standing (and walking)</b>																										
1		Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2														
2		Standing, no body support (for other restrict. see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13	0													
3		Bent forward (20-60°) with suitable support	2	3	5	7	9,5	12	18	23	32	40														
4		Strongly bent forward (>60°) with suitable support	3,3	5	8,5	12	17	21	30	38	51	63														
5		Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63														
6		Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100														
<b>Sitting</b>																										
7		Upright with back support slightly bent forward or backward	0	0	0	0	0	0	0,5	1	1,5	2														
8		Upright no back support (for other restrict. see Extra Points)	0	0	0,5	1	1,5	2	3	4	5,5	7														
9		Bent forward	0,7	1	1,5	2	3	4	6	8	11	13	1,17	5/8,8	1/1,76	1/1,76										
10		Elbow at / above shoulder level	2,7	4	7	10	13	16	23	30	40	50														
11		Hands above head level	4	6	10	14	20	25	35	45	60	75														
<b>Kneeling or crouching</b>																										
12		Upright	3,3	5	7	9	12	15	21	27	36	45														
13		Bent forward	4	6	10	14	20	25	35	45	60	75														
14		Elbow at / above shoulder level	6	9	16	23	33	43	62	80	108	135														
<b>Lying or climbing</b>																										
15		(Lying on back, breast or side) arms above head	6	9	15	21	29	37	53	68	91	113														
16		Climbing	6,7	10	22	33	50	66																		
1)		0	1	3	5	2)		0	1	3	5	Σ	8,8	1,76												
int		slightly	medium	strongly	extreme	int		close	60%	80%	arm stretched	1,17	Σ (max = 15)	Σ (max = 15)	Σ (max = 10)											
dur		≤10°	15°	25°	≥30°	dur		never	4 sec	10 sec	13 sec		Σ (max. = 40)													
		0	1,5	2,5	3			0	1	1,5	2	10,56														
		never	4 sec	10 sec	13 sec			never	4 sec	10 sec	13 sec															
		0%	6%	15%	20%			0%	6%	15%	20%															
Attention: Max. duration of evaluation = duration of task or 100%!																										
Attention: correct evaluation, if duration of evaluation ≠ 60s																										
Postures = Σ lines 1 - 16			1,17 (a)		+		10,56 (b)		=		11,73															

## Ergonomic Assessment Worksheet V1.3.4

Action forces (per minute / shift)										Forces																																																																																		
17		~ 90 N / twist Forces onto fingers (e.g. clips, plugs) < 15 twists								Intensity x time 1.2 x 2.5	Σ	3																																																																																
			<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td></td> <td>0</td> <td>1</td> <td>1.5</td> <td>2</td> <td>3.5</td> <td>7</td> <td></td> </tr> <tr> <td>-1/8 F<sub>max</sub></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>-1/3 F<sub>max</sub></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>-1/2 F<sub>max</sub></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>-2/3 F<sub>max</sub></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>F<sub>max</sub></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>[sec]</td> <td>3</td> <td>6</td> <td>9</td> <td>12</td> <td>20</td> <td>30</td> <td></td> </tr> <tr> <td>[%</td> <td>5</td> <td>10</td> <td>15</td> <td>20</td> <td>33</td> <td>50</td> <td></td> </tr> <tr> <td>0</td> <td>1.5</td> <td>2</td> <td>2.5</td> <td>3</td> <td></td> <td></td> <td></td> </tr> <tr> <td>[N]</td> <td>4</td> <td>10</td> <td>15</td> <td>20</td> <td></td> <td></td> <td></td> </tr> </table>											0	1	1.5	2	3.5	7		-1/8 F <sub>max</sub>								-1/3 F <sub>max</sub>								-1/2 F <sub>max</sub>								-2/3 F <sub>max</sub>								F <sub>max</sub>								[sec]	3	6	9	12	20	30		[%	5	10	15	20	33	50		0	1.5	2	2.5	3				[N]	4	10	15	20			
				0	1	1.5	2	3.5	7																																																																																			
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18		~ 10 N / hand Forces onto arms / whole body forces open and close								Intensity x time Left 0 x 1.5 Right 0 x 1.5	Σ	0																																																																																
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										Posture A1 (power grip, pliers, etc 70%)																																																																																		
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Data based on the "Assembly specific force atlas" (Wakui, Berg, Schwab, Glöckl, Egeleit 2008, adapted neutral to gender)										Attention: correct evaluation, if duration of evaluation ≠ 60s																																																																																		
Action forces = Σ lines 17 - 18										= 3																																																																																		

Manual Material Handling (per shift)										Loads																																																																																																
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1) Maximal cumulative time points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15																																																																																																										

## Ergonomic Assessment Worksheet V1.3.4

### Upper limb load in repetitive tasks Upper Limbs

**Force & Frequency & Grip (FFG)** Basic: number of real actions per minute or percent static actions (analyze only the most loaded limb)

Force [N]	Calc Stat			Static actions (sec/min)					Grip				Dynamic actions (real actions/min)								Calc Dyn				
	FFG	GS	%	FFGp	>45	30	20	10	5	3	0	2	4	2	10	15	20	25	30	35	>40	FFG	%	FFGp	
0 - 5					1	1	0	0	0	0	abc				0	0	0	1	2	3	4	7			
> 5 - 20	1	0	100	1	4	2	1	0	0	0	(ab)	bc			0	0	1	2	3	4	6	9			
> 20 - 35					7	5	3	2	1	1	ab	b	c		0	1	2	3	4	6	8	12			
> 35 - 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18	3	100	3	
> 90 - 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24				
> 135 - 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32				
> 225 - 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40				

20a  $FFG = \sum FFGp$  100% FFG = FFGS + FFGD 4 FFG FFGD = \sum FFGp 3

**Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)**

Wrist (deviation, flex, extens.)	Elbow (pron, sup, flex, extens.)			Shoulder (flexion, extension, abduction)			
	>15°	>20°	>45°	>60°	>60°	>60°	>20°
Posture points	10%	25%	33%	50%	65%	85%	PP
	0	0.5	1	2	3	4	

**Additional factors**

Gloves inadequate (which interfere with the handling ability required) are used for over half the time	2	<input type="checkbox"/>
Working gestures required imply a countershock. Frequency of 2 time per minute or more (i.e.: hammering over hard surface)	2	<input type="checkbox"/>
Working gestures imply a countershock (using the hand as a tool) with freq. of 10 time per hour or more	2	<input type="checkbox"/>
Exposure to cold or refrigeration (less than 0 degree) for over half the time	2	<input type="checkbox"/>
Vibrating tools are used for 1/3 of the time or more	2	<input type="checkbox"/>
Tools with a very high level of vibrations	4	<input type="checkbox"/>
Tools employed cause compressions of the skin (rednesses, callusities, blebs, etc.)	2	<input type="checkbox"/>
Precision tasks are carried out for over half the time (tasks over areas smaller than 2-3 mm)	2	<input type="checkbox"/>
More than one additional factor is present at the same time and overall occupy the whole of the time	3	<input type="checkbox"/>
<b>Additional points (choose the highest value)</b>	=	AF

**Repetitive tasks duration**

Duration [h/shift]	< 1		1.5		3		5		7		> 8	
	1	1.5	3	5	7	10						
Duration Points												
Work Organization	Breaks are possible at every time			Breaks are possible at given conditions			Breaks lead to a stop of the process					
	(Cycle time longer than 10 minutes)			(Cycle time between 1 and 10 minutes)			(Cycle time shorter than 1 minute)					
Work Organization Points	0			1			2					
Breaks (≥ 8 min) [h/shift]	0	1	2	3	4	5	6	≥7				
Break points	cycle time ≤ 30 sec		3	2	1	0	-1	-2	-3	-4		
	cycle time > 30 sec		0		-0.5		-1		-1.5		-2	
Duration Points	=											DP

**Upper limb load in repetitive tasks**

20 ( (a) Force & Frequency & Grip  $FFG$  + (b) Postures  $PP$  \* (c) Additional factors  $AF$  ) X (d) Duration  $DP$  = Upper Limbs



## Appendix B - Cost Analysis

	Regular	Zigzag		Two Doors		Four Bars	Double Slider-Crank	
		Left	Right	Left	Right			
<b>Door Dimensions (cm)</b>	1124.48	845.62	933.18	228.50	238.50	1124.48	634.00	
	248.00	202.07	195.16	1289.00	730.37	248.00	1109.32	
	441.50	184.00	1021.79	650.95	250.95	441.50	441.50	
	1305.00	929.16	214.33	724.38	827.54	1305.00	238.27	
	650.00					650.00	1289.00	
<b>Total Parameters (cm)</b>	376.90	452.53		494.02		376.90	371.21	
<b>Laser Cutting Cost (\$)</b>	22.26	26.72		29.17		22.26	21.92	
<b>Door Weight (kg)</b>	23.31	5.70	6.46	6.07	6.96	23.31	35.00	
<b>Total Weight (kg)</b>	23.31	12.16		13.03		23.31	35.00	
<b>Material Cost (\$)</b>	23.31	12.16		13.03		23.31	35.00	
	Lock #1	Hinge #1	Lock #1	Hinge #1	Lock# 1	Hinge #2	Lock#2	Lock#2
<b>Standard Parts (Units)</b>	1	2	1	4	1	4	2	1
<b>Standard Parts Cost (\$)</b>	15.58	12.86	15.58	25.72	15.58	25.72	46.08	23.04
<b>Total Standard Parts Cost (\$)</b>	28.44		41.30		41.30		46.08	23.04
<b>Custom Parts Cost (\$)</b>							35.48	275.30
<b>Total Cost (\$)</b>	74.00	80.18		83.51		127.13	355.26	
<b>Relative Cost</b>	1.00	1.08		1.13		1.72	4.80	

Table 1 Detail Cost Analysis for all designs

Laser Cutting Rate = \$0.059055/cm

Material Cost Rate = \$1/kg

Standard Parts Cost

Hinge # 1 = \$6.43/unit

Hinge # 2 = \$6.43/unit

Lock # 1 = \$15.58/unit

Lock # 2 = \$23.04/unit

Parts Name	Weight (kg)	Number (unit)	Material Cost (\$)	Labor (hr)	Labor Cost (\$)	Total Cost (\$)
<b>Cube</b>						
Wheel Chassis	0.22	8	1.77	0.42	52.08	53.85
Slider Limiter	0.21	4	0.82	0.25	15.63	16.45
Guide	1.30	4	5.20	0.50	31.25	36.45
<b>Cylinder</b>						
Outer Wheel	0.08	8	0.66	0.25	31.25	31.91
Inner Wheel	0.00	8	0.04	0.17	20.83	20.87
Rolling Pin	0.00	96	0.03	0.03	50.00	50.03
Top Pin	0.14	1	0.14	0.17	2.60	2.74
Slider-Crank Hinge	0.01	2	0.02	0.17	5.21	5.23
<b>Casting</b>						
Bearing Cap	0.01	4	0.04	0.25	15.63	15.67
Slider Base	2.10	2	4.20	0.75	23.44	27.64
Hood Block	0.03	1	0.03	0.17	2.60	2.63
Crank Linker	1.30	1	1.30	0.12	1.82	3.12
Crank	2.20	1	2.20	0.42	6.51	8.71
<b>Sheet Metal</b>						
Hood	2.40	1	2.40	0	0	2.40
Door	3.50	1	3.50	0	0	3.50
<b>Total</b>			16.45		258.85	275.30

Table 2 Detail Cost Analysis for the Double Slider-Crank's custom parts

Material Cost Rate = \$1/kg

Labor Cost Rate = \$15.625/hr

Parts Name	Weight (kg)	Number (unit)	Material Cost (\$)	Labor (hr)	Labor Cost (\$)	Total Cost (\$)
<b>Hinge (no hole)</b>	0.24	2	0.47	0.25	7.81	8.28
<b>Hinge (2 holes)</b>	0.41	2	0.82	0.33	10.42	11.23
<b>Bar (curve)</b>	0.92	4	3.67	0.08	5.21	8.88
<b>Bar (no curve)</b>	1.88	1	1.88	0.33	5.21	7.09
<b>Total</b>			6.84		28.65	35.48

Table 3 Detail Cost Analysis for the Four Bar's custom parts

Material Cost Rate = \$1/kg

Labor Cost Rate = \$15.625/hr