Return on Investment of a Pre-Reflow AOI System

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Abstract

This paper describes the losses from defects at the placement process in the SMT line. Two case studies of European and Taiwanese SMT manufacturers illustrate the actual losses from their defects. An evaluation method to select a pre-reflow AOI system maximizing the return on investment (ROI) is introduced. In the end, ROIs of three commercial pre-reflow AOI systems are compared to demonstrate the importance of selecting an appropriate AOI system. This paper will increase the probability that anyone installing an AOI system during the pre-reflow process will obtain a successful gain with short payback period.

Defect distribution at SMT processes

When process quality is at a world-class level, screen printing and component placement are, most likely, the two largest causes of defects (see exhibit 1). The defect rate caused by problems associated with the printing process is 51%, and defect rate due to low placement quality is 38%. Losses from these defects are not only material and labour costs but also indirect manufacturing cost, warranty, customer satisfaction and opportunity costs.

Potential gain from investment in pre-reflow AOI system

A pre-reflow AOI system not only prevents defective panel from proceeding to the next processes but also reduces manufacturing defects by detecting process problems earlier. This allows corrective action to take place sooner. Therefore, the AOI system can provide significant cost savings in the form of direct material and labour cost as well as manufacturing overhead. In addition, opportunity cost and invisible earnings from reducing total number of defects need to be considered as well.

The following two cases studies present the actual losses from defects at placement process. Exhibits 2 and 4 show the cost saving from a pre-reflow AOI system installed in a European automobile manufacturing company. This company requires that circuit board assemblies are not reworked in any way as the products perform critical safety function.

In this example, the losses at each manufacturing line from scrapping placement defects are $27,796/month or $333,552/year. When these defects are detected, significant cost savings can be realized from the disposed components and panels without rework process.

Exhibits 3 and 5 illustrate the cost saving from pre-reflow AOI system in Taiwanese mobile device manufacturing company. Rework process can be acceptable for the products as they perform non-critical functions, or are part of a non-critical system.

In this company's case, the losses caused by placement defects are $29,439/month or $353,268/year, and about 90% of losses are due to rework cost.

Cost of investment in pre-reflow AOI system

The losses from placement defects can be eliminated by placing an AOI system in the SMT line to ensure that no bad product will escape from the placement process. However, the actual cost of investment in the pre-reflow AOI system is very much dependent upon the price and performance of the system.

Exhibits 6 and 8 are comparison tables presenting the total cost of ownership of 3 different types of commercial AOI systems in the above-mentioned European SMT manufacturer. Exhibits 7 and 9 are comparison tables for above-mentioned Taiwanese SMT manufacturer. In both cases, CyberOptics' AOI system has the lowest cost of ownership, despite slightly higher initial cost than the lower cost Company A system. These comparisons indicate that the following key parameters need to be considered for selecting an AOI system to achieve minimum cost of ownership.

- Equipment cost
- Troubleshooting cost
- Maintenance cost
- Training cost
- Programming cost
- False call handling cost

Return on investment

Exhibits 10 and 11 present the ROI and payback period of 3 different types of commercial AOI systems in European automobile SMT manufacturer and Taiwanese mobile device SMT manufacturer. ROI of the CyberOptics AOI system used in Taiwanese mobile device company has the highest ROI of 414% with less than 4 months of payback period, while the ROI of the B Company in European automobile company is almost zero.

Conclusions

The potential gain from a pre-reflow AOI system is significant. However, there are critical features that need to be considered to select an appropriate pre-reflow AOI system in various manufacturing environments. Otherwise, the cost of ownership might be higher than the gain from defect prevention. CyberOptics' AOI system is designed to maximize return on investment for pre-reflow applications, and outperforms both slightly lower and higher initial cost AOI competitive systems.

Appendix

Exhibit 1. Percentage of defect distribution for world-class process quality

(Reference: CyberOptics market research)

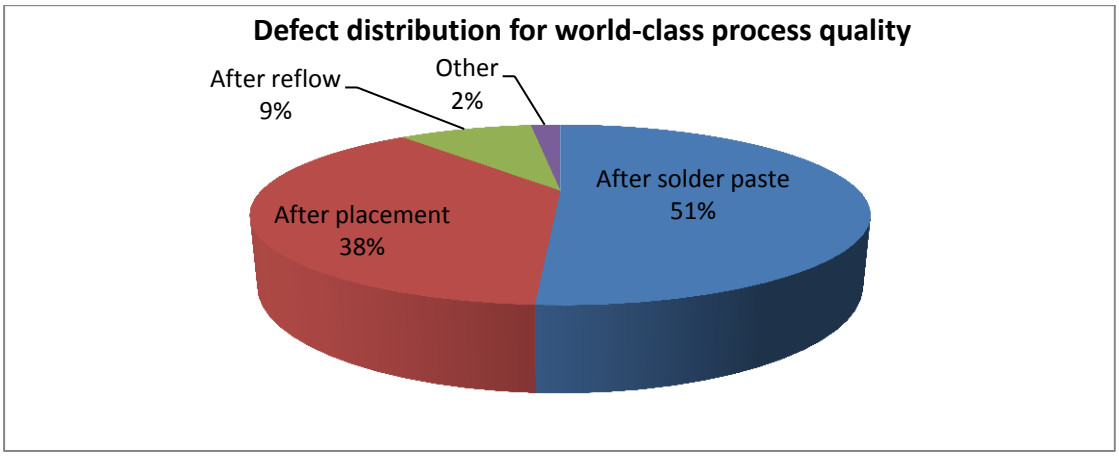

Exhibit 2. Raw data from a European SMT manufacturer

No	Item	Value	Unit
1	Avg. line cycle time /panel	35	seconds
2	Productivity	82%	
3	Avg. # panel /line/day	2,024	panels
4	# of line /factory	6	lines
5	# of panels manufactured /factory /month	364,361	panels
6	Total defect rate	1.030%	
7	Defect rate at pre-reflow due to placement machine	0.412%	
8	# of defect panels /month	1,501	EA
9	Avg. # of components on a panel	1,000	EA
10	Avg. # of scrapped components w/o rework /month	1,501,168	EA
11	Avg. one panel cost	$5	
12	Avg. one component cost	$0.09	
13	Avg. rework cost	$120	
14	Avg. loss from defect panel /month	$7,506	
15	Avg. loss from component w/o rework /month	$135,105	
16	Avg. # of labour/ line	2	Persons
17	Avg. operator's monthly wage	$2,400	
18	Total monthly labour cost /factory	$28,800	
19	Wasted Avg. labour cost /month	$119	
20	Wasted Avg. Indirect labour cost /month (20% overhead)	$24	
21	Wasted Avg. Indirect material cost - w/o rework /month (5% overhead)	$7,131	
22	Wasted Avg. Indirect material cost – Rework /month (5% overhead)	$7	
23	Other Indirect manufacturing cost /month (Machine depreciation, rental, electricity, etc.)	$3,000,000	
24	Wasted Avg. other Indirect manufacturing cost /month	$12,360	
25	Avg. monthly revenue	$10,000,000	
26	Avg. Net profit margin (revenue – cost)/revenue	11%	
27	Avg. monthly profit	$1,100,000	
28	Opportunity cost due to placement defect /month (profit x placement defect rate)	$4,532	

Currency: U.S. Dollar

Exhibit 3. Raw data from a Taiwanese SMT company

No	Item	Value	Unit
1	Avg. line cycle time /panel	40	seconds
2	Productivity	77%	
3	Avg. # panel /line/day	1,663	panels
4	# of line /factory	10	lines
5	# of panels manufactured /factory /month	498,960	panels
6	Total defect rate	1.322%	
7	Defect rate at pre-reflow due to placement machine	0.529%	
8	# of defect panels /month	2,639	EA
9	Avg. # of components on a panel	1,000	EA
10	Avg. # of scrapped components w/o rework /month	2,638,500	EA
11	Avg. one panel cost	$4	
12	Avg. one component cost	$0.08	
13	Avg. rework cost	$100	
14	Avg. loss from defect panel /month	$10,554	
15	Avg. loss from component w/o rework /month	$211,080	
16	Avg. # of labour/ line	3	Persons
17	Avg. operator's monthly wage	$1,500	
18	Total monthly labour cost /factory	$45,000	
19	Wasted Avg. labour cost /month	$238	
20	Wasted Avg. Indirect labour cost /month (20% overhead)	$48	
21	Wasted Avg. Indirect material cost - w/o rework /month (5% overhead)	$11,082	
22	Wasted Avg. Indirect material cost – Rework /month (5% overhead)	$11	
23	Other Indirect manufacturing cost /month (Machine depreciation, rental, electricity, etc.)	$4,400,000	
24	Wasted Avg. other Indirect manufacturing cost /month	$23,267	
25	Avg. monthly revenue	$16,000,000	
26	Avg. Net profit margin (revenue – cost)/revenue	8%	
27	Avg. monthly profit	$1,280,000	
28	Opportunity cost due to placement defect /month (profit x placement defect rate)	$6,769	

Currency: U.S. Dollar

Exhibit 4. Monthly gain from a pre-reflow AOI system in a European SMT manufacturer

No	Item	Description	Equation	Total cost
1	Average material cost (Direct Cost)	Components and panels	(14)+(15)	$142,611
2	Average labour cost (Direct Cost)	Labour cost for manufacturing	(19)	$119
3	Indirect labour cost (Manufacturing Overhead)	Supervisors, logistic team, etc.	(20)	$24
4	Indirect material cost (Manufacturing Overhead)	Water, grease, chemicals, etc.	(21)	$7,131
5	Other indirect manufacturing cost (Manufacturing Overhead)	Machine depreciation, land rent, property, electricity, transportation, factory operations, etc.	(24)	$12,360
6	Opportunity cost	profit x placement defect rate	(28)	$4,532
7	Invisible earnings	Reduced lead time Increased customer satisfaction	N.A	N.A
			Monthly gain/Factory	**$166,776**
			Monthly gain/Line	**$27,796**
			Cost/defect panel	**$111.10**

Exhibit 5. Monthly gain from a pre-reflow AOI system in a Taiwanese SMT manufacturer

No	Item	Description	Equation	Total cost
1	Average material cost (Direct Cost)	Devices, panels, etc	(8) * (12)	$211
2	Average labour cost (Direct Cost)	Labour cost for manufacturing	(19)	$238
3	Average rework cost (Direct Cost)	Labour cost for rework	(8) * (13)	$263,850
4	Indirect labour cost (Manufacturing Overhead)	Supervisors, logistic team, etc	(20)	$48
5	Indirect material cost (Manufacturing Overhead)	Water, grease, chemicals, etc	(22)	$11
6	Other indirect manufacturing cost (Manufacturing Overhead)	Machine depreciation, land rent, property, electricity, transportation, factory operations, etc	(24)	$23,267
7	Opportunity cost	profit * placement defect rate	(28)	$6,769
8	Invisible earnings	Reduced lead time Increased customer satisfaction	N.A	N.A
			Monthly gain/Factory	**$294,393**
			Monthly gain/Line	**$29,439**
			Cost/defect panel	**$111.58**

Exhibit 6. Details of cost of ownership of three different types of AOI system in European SMT manufacturer

No	Item	A company AOI	B company AOI	CyberOptics AOI	Unit
1	AOI cost	$70,000	$150,000	$90,000	
2	AOI system depreciation cost/month (6 yrs life time)	$972	$2,083	$1,250	
3	MTBF	720	1,440	10,000	hours
4	MTTR	12	24	3	hours
5	# of hours for troubleshooting/month	12.00	12.00	0.22	hours
6	Troubleshooting service charge/hour	$120	$120	$120	
7	Troubleshooting cost/month	$4,496	$4,496	$81	
8	MTBM	720	1,440	10,000	hours
9	MMT	12	16	6	hours
10	Maintenance time/month	12.00	8.00	0.43	hours
11	Maintenance serivce charge/hour	$60	$60	$60	
12	Maintenance cost/month	$3,776	$2,517	$136	
13	Training service charge/hour	$40	$40	$40	
14	# of hours for operator training	32	40	16	hours
15	Operator turn-over rate/year	1	1	1	
16	Training cost/month	$107	$133	$53	
17	Programing time	4	6	2	hours
18	# of panel model change/month	10	10	10	
19	# of hours for model change/month	40	60	20	hours
20	Programing technician wage/hour	$40	$40	$40	
21	Programing cost/month	11,785	17,678	5,893	
22	False call rate	0.09%	0.07%	0.05%	
23	# of panels manufactured/month	60,727	60,727	60,727	EA
24	# of components/month	60,726,857	60,726,857	60,726,857	EA
25	# of false call panel/month	54,654	42,509	30,363	EA
26	False call handling time/component	5	5	5	seconds
27	False call handling time/month	76	59	42	hours
28	# of Manpower to handle false calls/month	0.47	0.37	0.26	persons
29	Operator's wage/month	$2,400	$2,400	$2,400	
30	False call handling cost/month	$1,138.63	$885.60	$632.57	lines
31	AOI delta process time	0	1	0	seconds
32	# less panel due to AOI delta process time	0	56	0	
33	Cycle time cost	$0.0	$169.8	$0.0	
34	Opportunity cost /hours	$254.63	$254.63	$254.63	

Exhibit 7. Details of cost of ownership of three different types of AOI system in Taiwanese SMT manufacturer

No	Item	A company AOI	B company AOI	CyberOptics AOI	Unit
1	AOI cost	$50,000	$120,000	$75,000	
2	AOI system depreciation cost/month (6 yrs life time)	$694	$1,667	$1,042	
3	MTBF	720	1,440	10,000	hours
4	MTTR	12	24	3	hours
5	# of hours for troubleshooting/month	12.00	12.00	0.22	hours
6	Troubleshooting service charge/hour	$100	$100	$100	
7	Troubleshooting cost/month	$3,333	$3,333	$60	
8	MTBM	720	1,440	10,000	hours
9	MMT	12	16	6	hours
10	Maintenance time/month	12.00	8.00	0.43	hours
11	Maintenance serivce charge/hour	$50	$50	$50	
12	Maintenance cost/month	$2,733	$1,822	$98	
13	Training service charge/hour	$30	$30	$30	
14	# of hours for operator training	32	40	16	hours
15	Operator turn-over rate/year	1	1	1	
16	Training cost/month	$80	$100	$40	
17	Programing time	4	6	2	hours
18	# of panel model change/month	10	10	10	
19	# of hours for model change/month	40	60	20	hours
20	Programing technician wage/hour	$30	$30	$30	
21	Programing cost/month	8,311	12,467	4,156	
22	False call rate	0.09%	0.07%	0.05%	
23	# of panels manufactured/month	49,896	49,896	49,896	EA
24	# of components/month	49,896,000	49,896,000	49,896,000	EA
25	# of false call panel/month	44,906	34,927	24,948	EA
26	False call handling time/component	5	5	5	seconds
27	False call handling time/month	62	49	35	hours
28	# of Manpower to handle false calls/month	0.39	0.30	0.22	persons
29	Operator's wage/month	$1,500	$1,500	$1,500	
30	False call handling cost/month	$584.72	$454.78	$324.84	lines
31	AOI delta process time	0	1	0	seconds
32	# less panel due to AOI delta process time	0	41	0	
33	Cycle time cost	$0.0	$104.1	$0.0	
34	Opportunity cost /hours	$177.78	$177.78	$177.78	

Exhibit 8. Monthly total cost of ownership in European SMT manufacturer

No	Item	A company AOI	B company AOI	CyberOptics AOI
1	AOI system depreciation cost/month (6 yrs life time)	$972	$2,083	$1,250
2	Troubleshooting cost/month	$4,496	$4,496	$81
3	Maintenance cost/month	$3,776	$2,517	$136
4	Training cost/month	$107	$133	$53
5	Programing cost/month	$11,785	$17,678	$5,893
6	False call handling cost/month	$1,139	$886	$633
7	Opportunity cost/equipment/month	$0	$170	$0
	Monthly total cost of ownership	**$22,274**	**$27,962**	**$8,045**

Exhibit 9. Monthly total cost of ownership in Taiwanese SMT manufacturer

No	Item	A company AOI	B company AOI	CyberOptics AOI
1	AOI system depreciation cost/month (6 yrs life time)	$694	$1,667	$1,042
2	Troubleshooting cost/month	$3,333	$3,333	$60
3	Maintenance cost/month	$2,733	$1,822	$98
4	Training cost/month	$80	$100	$40
5	Programing cost/month	$8,311	$12,467	$4,156
6	False call handling cost/month	$585	$455	$325
7	Opportunity cost/equipment/month	$0	$41	$0
	Monthly total cost of ownership	**$15,737**	**$19,884**	**$5,720**

Exhibit 10. ROI and payback period of AOI systems in European SMT manufacturer

No	Type of AOI system	Return/month	ROI	Payback period (Month)
1	A company AOI	$5,522	24.79%	12.68
2	B company AOI	-$166	-	-
3	CyberOptics AOI	$19,751	245.49%	4.56

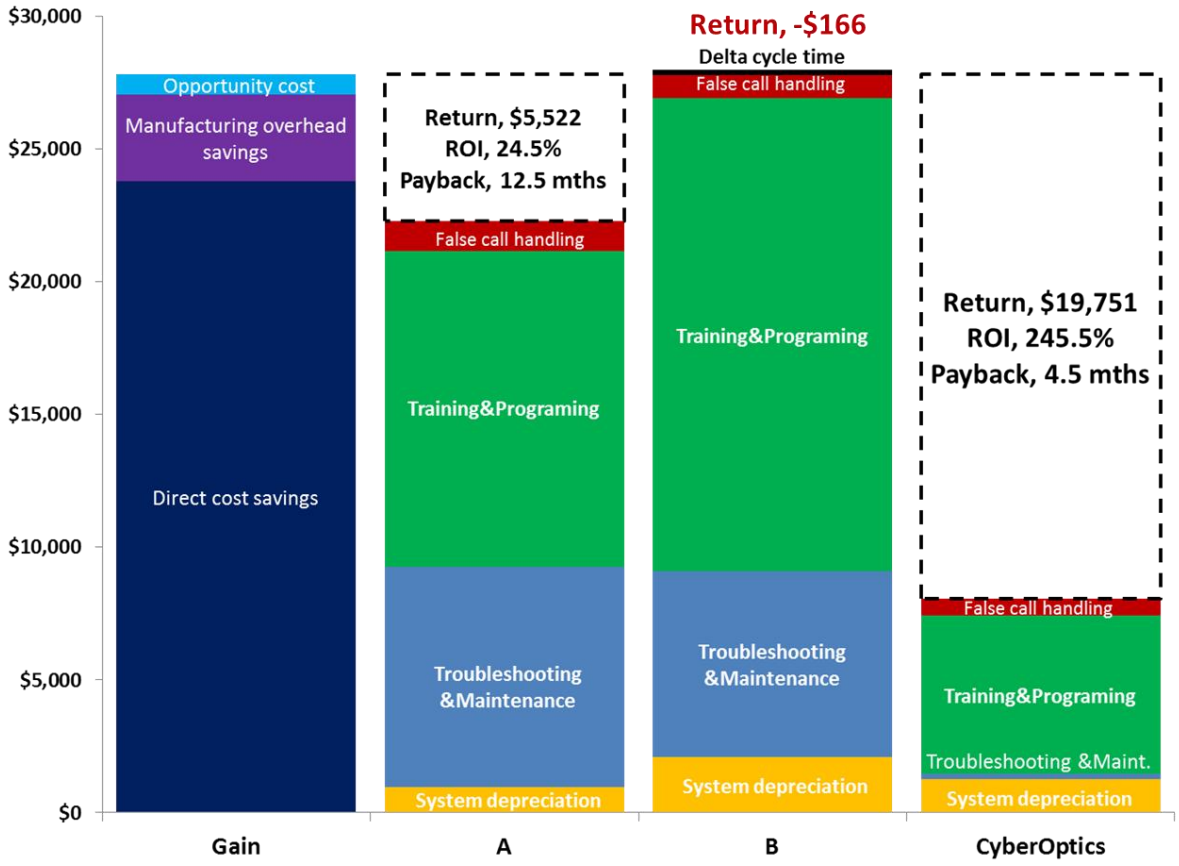

Exhibit 11. ROI and payback period of AOI systems in Taiwanese SMT manufacturer

No	Type of AOI system	Return/month	ROI	Payback period (Month)
1	A company AOI	$13,702	87.07%	3.65
2	B company AOI	$9,555	48.05%	12.56
3	CyberOptics AOI	$23,719	414.63%	3.16