Improvement potentials in Swedish electronics manufacturing industry – Analysis of five case studies

(article starts on next page)

45th CIRP Conference on Manufacturing Systems 2012

Improvement Potentials in Swedish Electronics Manufacturing Industry – Analysis of Five Case Studies

R. Sundkvist[a],*, R. Hedman[a], P. Almström[a], A. Kinnander[a]

[a]Department of Materials and Manufacturing Technology, Chalmers University of Technology, Hörsalsvägen 7, 412 96 Gothenburg, Sweden
* Corresponding author. Tel.: +46-31-772 13 12; E-mail address: robin.sundkvist@chalmers.se

Abstract

A method for analysing the profitability of manufacturing facilities has been developed to understand how to improve the competitiveness of the Swedish electronics manufacturing industry. This paper presents the results of five case studies carried out at Swedish electronics manufacturers. During these case studies the method has been tested and further developed. Several areas of improvement have been identified with focus on productivity increase of surface mount assembly lines and manual through-hole assembly. Since the characteristics of the studied production facilities can be found world wide, it's assumed that the results can be valid at least in other high-cost countries.

Keywords: Productivity; Electronics manufacturing industry; Profitability

1. Introduction

This article report the result from five case studies carried out in the Swedish electronics industry. The overall purpose of the studies was to develop and test a new method for profitability analysis of a complete factory in a very limited amount of time.

The starting point for the development of the new method called Production System Analysis (PSA) was the Productivity Potential Assessment (PPA) method previously developed by the research group [1]. The PPA method and the PSA method are described in section 2.

The area of application for PPA is manufacturing industry in general. The PSA method was developed as a part of a larger project called Chalmers Electronics Production project with the overall purpose of strengthening the Swedish electronics industry by introducing novel design solutions as well as improving the existing production systems. The cases reported in this article is therefore from the application of PSA or different parts of PSA as the PSA method is still under development and no study has yet been made using the complete and final version. Even though the method is still in progress, different data and measures have been collected that together provides a quite comprehensive idea about the improvement potential in the electronics industry. All participating companies produce similar products (circuit boards and complete "box builds") and have similar production system structure (first automatic surface assembly and then manual assembly, testing and packaging). The studied companies mainly compete by being flexible and reliable, not by having the lowest cost.

2. Productivity

Productivity is a well-known and established term in the manufacturing industry. It describes the relationship between the products being produced and the amount of resources being used in the transformation process [2]. Thus, productivity is commonly defined as output (e.g. number of assembled cars, computers, or speakers) divided by input (e.g. per time unit, per employee, or per capita) [3]. For manufacturing activities, productivity or

productivity improvement can be expressed as equation 1 and 2 [1] [4] [5]. Equation 1 is valid for manual activities (operations with manual work content) and eq. 2 is valid for automatic activities (operations performed by machines).

$$Productivity = Method\ (M) \times Performance\ (P) \times Utilization(U) \qquad (1)$$

The M factor (in eq. 1) is the productivity measure of an individual operation or activity performed at the shop floor. An example is "number of assembled objects per time unit". The M value for manual operations is determined by a pre-determined time system (PTS) such as Methods-Time-Measurement (MTM) 1, 2, or 3 [6] or the Sequence Based Activity and Method Analysis (SAM) [7]. The M value for machine operations is usually calculated in process planning activities using Computer Aided Manufacturing (CAM) software and various simulation tools. By using a pre-determined time system, it is possible to provide each operation within a production system with a standard time. In addition to offering a given standard time, a method study will also make it possible to compare a current state with a proposed future state, i.e. establish a future state M value based on operation improvements. An example of improving the M value is to change from a manual screwdriver operation to an electrical screwdriver operation. The operation may be ten times more efficient because of the change in method. The improvement can be visualized and understood quantitatively by comparing the productivity ratio before and after the change. However, the introduction of the screwdriver also represents an investment. Improvements of M will often result in a need for investments. The exception is smaller method changes, like excluding unnecessary steps by moving material closer to the work area.

The P factor in eq. 1 refers to the speed that the activity is carried out at in practice. The performance rate is determined by comparison with normal speed. Normal speed for manual work is defined by an accepted PTS like MTM. The normal speed is set at a level that is ergonomically acceptable for the average operator. Performance losses are usually a matter of lack of skills or motivation.

The U factor in equation 1 equals the portion of the planned production time that actually has been used to create value for the customer. For example, if the planned production time for a manual work operation is set to 60 hours per week and the actual production time is only measured to be 30 hours per week, the utilization parameter is set to 0,5 (50%). Common utilization problems are long set-up times, adjustments, break-downs, idling and small stops. The U factor for manual work is measured through a work sampling study [6].

Automatic activities or activities where the major part of the value adding work is performed by machines are measured using Overall Equipment Effectiveness (OEE) [8]. The OEE measure is defined as the ratio between the total time that a machine is producing quality approved product and the total planned production time. For pedagogical reasons is OEE described as the product of three factors: Availability, Efficiency, and Quality:

$$OEE = Availability \times Efficiency \times Quality \qquad (2)$$

$$Availability = \frac{(Planned\ time - Stop\ time)}{Planned\ time} \qquad (3)$$

$$Efficiency = \frac{Ideal\ cycle\ time \times \#\ of\ items\ produced}{(Planned\ time - Stop\ time)} \qquad (4)$$

$$Quality = \frac{(\#\ of\ items\ produced - \#\ of\ defect\ items)}{\#\ of\ items\ produced} \qquad (5)$$

OEE has become a de facto standard in the manufacturing industry. However, there are several difficulties; one is to determine the ideal cycle time, another is to know the actual planned time for a batch if batch production is used. Utilization (U) in equation 1 is equal to Availability factor if small stops are included in Availability. That is possible if an automatic system is used to log disturbances. The efficiency factor is then equal to the Performance factor in equation 1. OEE doesn't include a Method (M) factor and is therefore not a productivity measure.

3. Case studies

The research presented here was performed as case studies. This approach was considered suitable for validating and further developing the theoretical model of the method PSA described in previous section. Results from case studies identify areas with improvement potential in Swedish electronics manufacturing industry.

In some of the cases, only parts of the theoretical model were tested. This was because during the studies empirical observations sometimes resulted in unanticipated issues which in turn were explored in complementary data collection that lead to expansion of the theoretical model. Dubois and Gadde [9] refer to this as systematic combining where theoretical framework, empirical framework and the case analysis evolve simultaneously. In addition, analysis was partially conducted parallel with collection of data. Throughout a one week case study there is a frequent overlap of data analysis with data collection. This is defined as matching, meaning how to build theory from case

studies. Instead of forcing data to fit in preconceived categories, it is asserted that the categories should rather be developed from data [9].

3.1 Five case companies

Five case studies were performed and consequently, five companies from the Swedish electronics production industry have been analysed. Four out of five companies are classed as SMEs, with a range of number of employees from 50 250, and one is considered as a large company.

3.2 Results and analysis

The productivity at the studied companies has been assessed with the productivity relationship in eq. 1 and with OEE (eq. 2). The productivity assessment has been made at important manufacturing sections - bottlenecks of main production processes. The current state (CS) of eq. 1 has been analysed with work sampling studies and SAM. The suggested solutions have not been implemented at any company, but the proposals have been used as input for future improvement work. No follow-ups have consequently not been possible to make, and thus the only valid future state (FS) value is derived from the use of SAM.

Table 1 shows the results from the productivity assessments. The type of resource being used classified the production activities. For production procedures that did not involve machines (e.g. manual assembly), the classification was "assembly" (ass.) and for procedures that involved machines, the classification was "operator" (op.). Table 1 provides a description to distinguish some differences in work method content. Even though the description in table 1 is set-up, differences in work method content could exist. That means that direct comparisons between the companies cannot be made. The set-up procedure's work method design was however similar (but not identical) at the companies. A strong reason for this was the use of same machine supplier. However, differences could be found in the organization and control of the machine lines. By improving work method design (minimize movements, improve work station design, facilitate usage of supporting tools and equipment etc.) a FS M value could be derived. In all cases with the operator classification, theoretical method improvements were found ranging from 11% (B) to 58% (D). The productivity measurement number of items per hour refers to the numbers of parts that were mounted into the machine or machine related equipment per time unit.

For manual work tasks, the same measurements were used, but referring to the number of electronic components that were handled during the work procedures. The latter measurement was more diverse since some of the procedures involved several activities such as through-hole mounting (THM), testing and packing (company A and D) that decreased the productivity results to a great extent. More importantly was the fact that improvements were found in all cases, ranging from 3 % (A) to 100% (D). The extreme case (D) was only possible due to a proposed machine investment that in theory solved a bottleneck problem.

The performance parameter P in equation 1 was neglected in most of the case studies. Clock studies were made in some but not all cases, to be compared with the normal time given by SAM. However, due to differences in training and experience among the study objects the results could vary between for example 2,5 to 6 minutes when the normal time was set to 3 minutes. It was also difficult to perform clock studies due to the inconsistency of the work procedures (especially true for machine operators). The cycle time for the work procedures continually changed depending on what product that was produced. However, since a significant variation in time was evident in most of the cases, one conclusion was a lack of standardized work methods and obviously lack of training and education in these matters. Another reason refers to the time consumption of using SAM. It was prioritized to analyse the normal time rather than the performance of the personnel to be able to create improvement proposals based on SAM. Thus, the analysts didn't have enough time to consider the performance parameter

The last parameter of equation 1 is the utilization (U) parameter. The general case showed that utilization for manual assembly operations (average 81%) was better than utilization for machine operators (average 75,6%). These results were in line with previous shop-floor utilization research [10]. The utilization parameter is strongly affected by the production system used by the companies, but also by the work method in use and the individual employee (training, fatigue and motivation etc.). The typical manual workstation in the electronics industry was designed for working with production batches. The same type of physical layout and production organization were found in most cases, basic workstations with simple tools. The utilization proved to be high, but overall facility operating performance proved to be low (table 2), especially inventory turnover, due to long internal lead times and high levels of work-in-process material. The results converge with the studied facilities levels of production engineering (table 3), which indicate that they have a potential to develop their production systems and thus a potential to strengthen their competitiveness.

The machine operators' utilization was more difficult to interpret since it influences inputs (costs) directly and indirectly affects output. The output is created by the

machines and the operators' utilization will affect the machines' utilization. The machine utilization was measured with OEE (eq. 2). Table 1 presents two types of OEE results, current state (CS) OEE and future state (FS) OEE based on possible improvements of the set-up methods. Measuring OEE for surface mounting assembly (SMA) equipment was however difficult, especially the efficiency and quality parameters of equation 2.

Table 1. Productivity assessment results.

	Company A		Company B		Company C		Company D		Company E	
Resources	*Ass.*	*Op.*	*Ass.*	*Op.*	*Ass.*	*Op. /Ass.*	*Ass.*	*Op.*	*Ass.*	*Op.*
Description	THM[a]-to-packing	Set-up	THM	Set-up	THM	Pre-paration	THM-test-etc.	Set-up	THM	Set-up
M_{CS}	138 items/h	54 items/h	1077 items/h	54 items/h	1133 items/h	2577 items/h	200 items/h	46 items/h	966 items/h	54 items/h
M_{FS}	142 items/h	70 items/h	1363 items/h	60 items/h	N/A	N/A	400 items/h	72,6 items/h	1242 items/h	69 items/h
$M_{improvement}$	+2,9%	+29,6%	+26,6%	+11,1%	N/A	N/A	+100%	+57,8%	+28,6%	+27,8%
P	85%	N/A[b]	100%	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
U	89%	70%	77%	90%	75%	82%	81%	66%	83%	70%
$M_{CS}xPxU$	104,4 items/h	37,8 items/h	829,3 items/h	48,6 items/h	849,7 items/h	1752 items/h	162 items/h	30,4 items/h	801,8 items/h	37,8 items/h
$M_{FS}xPxU$	107,4 items/h	49 items/h	1049,5 items/h	54 items/h	N/A	N/A	324 items/h	47,9 items/h	1030,8 items/h	48,3 items/h
OEE_{CS}	-	45%	-	40%	-	68%[c]	-	50%	-	45%
OEE_{FS}	-	50%	-	N/A[d]	-	N/A	-	55%	-	50%
$OEE_{improvement}$	-	+11,1%	-	N/A	-	N/A	-	+10%	-	+11,1%

Table 2. Key performance indicators

	Company A	Company B	Company C	Company D	Company E
Inventory turnover	7.4	N/A[e]	4.6	4(8)[f]	10[g]
Delivery precision	94%	N/A	81.5%	85%	N/A
Scarp rate	0.25%	N/A	N/A	<1%	N/A
Customer complaints	2500 ppm	N/A	1631 ppm	300 ppm	N/A

---

[a] THM = Through-hole mounting
[b] Performance analysis was not applied
[c] Selective soldering machine
[d] An external picking process was analysed and thus not affecting OEE
[e] Operating performance data collection was not made.
[f] The company did need to buy electronics components for up to 5 years need.
[g] The company had an in-house supplier storage.

The ideal speed of placing surface mounted components (SMCs) changes depending of what component being placed. That is, there are equally numbers of practical ideal machine efficiency values as the company have SMC part numbers, which are usually several thousands. The latter problem was tracked down to the reliability of the quality inspection equipment (the manual calibration of the equipment) in combination with how the SMA equipment reported quality errors. The OEE values in table 1 does only consider the availability parameter of eq. 2, and the true OEE values were thus less than those given in this report (average 45% when excluding C), which indicates that there is a great amount of unexploited capacity in the electronics manufacturing industry.

Table 3 presents a measurement that describes the production engineering level of the facilities (see section 2.2). The average score was 20 (maximum is 40) and the most evident improvement potentials were found in the following categories: Planning, continuous improvements, changeover, strategy and goals.

Table 3 : Level of production engineering.

	Company A	Company B	Company C	Company D	Company E
Level of production engineering	19	N/A	21	25	15

The lowest score was found at the company with the smallest revenue and the best score was found at the company with highest revenue. That could be a coincidence, but it is one indicator that suggests that improving the production system affects the financial performance of the company.

The objective of the PSA method is to translate the productivity performance measures to economical terms, with the rationale that adding information of future earnings from the suggested improvements, will give decision makers increased authority to actually perform productivity investments. In order to fulfil that objective, a financial analysis is done starting with the annual report at facility level. To make income statement comparisons between different facilities it's important to distinguish between normal costs (recurring) and exceptional costs (non-recurring) [11]. The companies' annual reports needed to be manually interpreted. That added some errors to the analysis. Table 4 presents the cost distribution of the five companies. The largest cost portion was found to be the material cost (average of 68% if company B is excluded). Company B had considerably more product development resources (labour costs) than the other companies. All other companies had labour costs ranging from 18-27%. A

remarkable figure is the low machine cost portion shown at all companies. Same type of component distributors supplied most of the companies that meant that the companies were competing under similar conditions. Thus, to gain competitive edge the companies should put their long-term strategic efforts into creating an efficient production system that minimize waste and utilize its resources in the best possible way. Since the machine and equipment costs were low, it must be more important to improve productivity in all manual operations to optimize the labour cost and create flexibility.

To measure profitability, the return-on-assets (ROA) ratio was selected. The relationship between ROA and shop floor utilization is examined with PSA, but so far no specific results can be presented. Some observed problems with using ROA in a short term analysis as PSA, is the difficulties of analysing the effects from historical events that formed the balance sheet to its current state and also to normalize the effects of surrounding events occurring during a full business cycle.

4. Conclusions

The case studies performed during the development of the PSA method have shown that there is a great potential of improving factory floor productivity in the Swedish electronics industry and thus in similar type of operations in other high-cost countries. The largest potential is found in the unused machine capacity. The low machine utilization is explained by the large number of customers in combination with a diverse and extensive product mix. The customers demand flexibility in terms of fast delivery with short notice. These conditions make e.g. changeovers to an important and often-recurring production activity. The importance of creating and sustaining an efficient production system that has the ability of coping with variations in demand and customer flexibility is thus evident. The most important way of creating the needed flexibility is probably to increase productivity of manual work tasks involved in the set-up of the SMA machines. To lower the costs is obviously important, but the studied companies cannot compete on cost with the so called low-cost countries in Eastern Europe and Asia.

An objective of the PSA method is to analyse how factory floor improvements affects the profitability of a company. A relationship between factory floor utilization (productivity) and financial performance has been researched. However, company wide financial performance is not solely dependent on production activities and isolating the links between productivity improvement actions and financial records have been

difficult to make. This is a continuing research goal and more investigations are needed to find those links.

None of the five companies did show exceptional good productivity results, which establish the idea that these companies don't prioritize cost to compete on the market. Instead, factors such as geographical proximity to customers and good customer relationships are more important. However, creating an efficient production system with high productivity through good methods and high utilization will most likely provide the individual company improved competitiveness in terms of increased flexibility and decreased costs.

Acknowledgements

References

[1] Almström P., and Kinnander A., 2011, "Assessing and benchmarking the improvement potential in manufacturing systems at shop-floor level", International Journal of Productivity and Performance Management, 60 (7) pp. 758-770.

[2] Bernolak, I., 1997. "Effective measurement and successful elements of company productivity: The basis of competitiveness and world prosperity.", Int. J. Production Economics, Vol. 52, pp. 203-213.

[3] Tangen, S., 2005. "Demystifying productivity and performance. ", Int. J. of Productivity and Performance Management, Vol. 54, No. 1, pp. 34-46.

[4] Saito, S., 2001. Case Study: Reducing labor cost using industrial engineering techniques in Zandin, K. (ed), Maynard's Industrial Engineering Handbook.

[5] Sakamoto, S., 2010. Beyond world-class productivity – Industrial engineering practice and theory, Springer-Verlag.

[6] Freivalds A., 2009, Niebel's Methods, Standards, and Work Place Design, McGraw-Hill, New York.

[7] IMD, International MTM Directorate, 2004. "SAM - Sequential Activity – and Methods Analysis - System description".

[8] Nakajima, S., 1988. Introduction to TPM: Total Productive Maintenance., (Productivity Press,: Cambridge, MA).

[9] Sundkvist, R., Almström, P., Kinnander, A., 2010. "A profitability assessment method for the electronics manufacturing industry", in the proceedings of the 10th manufacturing accounting research conference.

[9] Dubois, A., Gadde, L-E., 2002. "Systematic combining: an abductive approach to case research", Journal of Business Research, Vol. 55, pp. 553 – 560.

[10] Almström, P., Kinnander, A., 2008. "Results and Conclusions from the Productivity Potential Assessment Studies", in Proceedings of the 2nd Swedish Production Symposium

[11] White, G.I., Sondhi, A.C:, Fried, D., 2003. "The analysis and use of financial statements 3rd ed.", Wiley.