LINE BALANCING THE ROUTE TO PROFIT
IN ELECTRONICS MANUFACTURING

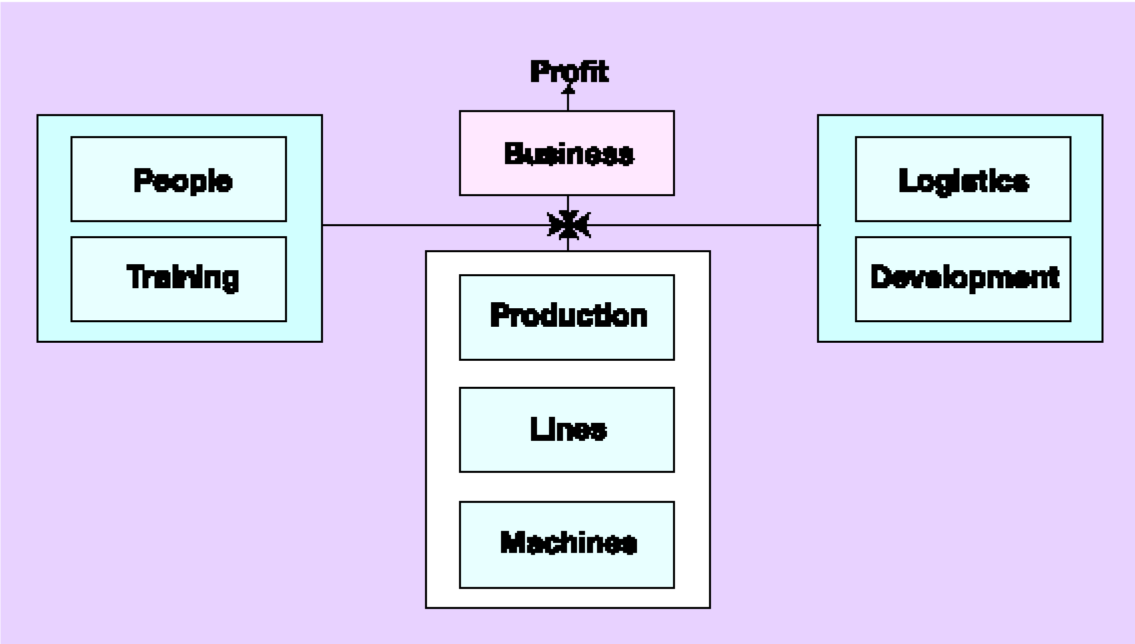
by Paul Gerits and Anton Mandos, Assembléon BV

The electronics business has been a rather heated, if not over-heated, environment for many years. This has lead to a forgiving climate regarding inefficiencies, as resources have not been stretched and getting products out has been top priority. It might now be time to invest in some reflection on the strategies and tactics applied to the production environment in order to be prepared for the 'heat' of the future. Focusing investment in the right resources, and not sub-optimising, is the way to go.

Balancing functionalities is not typically a concern in the production environment, but has a lot of impact on the total business performance. Production is directly dictated by the market requirements. A product's time to market, together with the trend towards an ever-higher content of features and frills, requires increasing flexibility on the production floor. The pressure on price, on the other hand, does not allow manufacturers to obtain this flexibility with slipping efficiency on the production line.

So balance…

It is important to have a complete company structure (Fig. 1) in balance, rather



than to focus exclusively on any single item within the structure. It does not improve business if logistics is optimised while human resources employs the wrong people. Similarly, to employ the correct people but fail to give them the correct training or education, does not provide the optimum production environment. Failure to optimise a single 'link', or even multiple 'links', will have a direct impact on the profit.

The significance of balance

Line balancing, which takes into account component, PCB and process variations, machine capabilities, logistics, development and operator performance, is essential to the achievement of optimum output with high quality and efficiency, leading to every manufacturer's goal – maximum profit with the best product on the market. Line balancing involves a discussion with all parties to the manufacturing process. It is not a discussion on technical issues but a case study, aiming to achieve the solution which is in the best interests of all parties, as shown in some real-life cases.

Case 1: penny wise…

A simple example shows how the purchasing department can destroy line balance. Suppose production asks purchasing to provide 100 000 of a certain component in 25 tapes. Purchasing goes out to the marketplace and discovers that it can save $200 by buying the 100 000 components in five tapes – unit volume has not been translated into what the production line actually needs for best performance. When the components arrive in production, they cannot be distributed over 25 feeder position as required. Therefore production across the line is re-shuffled, leading to line imbalance and reduced output, affecting line profit to a far greater extent than the purchase cost saving. Improved understanding between production, purchasing and finance departments can save money.

Case 2: big is beautiful…

Similarly, the production line is set up to manufacture a board measuring 200 by 180mm with high percent yield. Development decides to redesign the board to reduce product size, say to 100 by 100mm, for the simple reason that such a design 'looks' better, but forgetting there is a production facility to be taken into account. This redesign could, for example, generate costs for new machine options on the production line. Alternatively, the board might have been re-sized to be manufactured in multiples, for example 360 by 400mm, requiring no machinery changes or, even better, making more use of machine capabilities. In practice, in 95 percent of cases it costs less to re-design the board than to set up production. Improved communication between development and production departments can save costs.

Which balance to use

Only a small part of line balancing relates to the equipment itself, but it is an essential part. Distribution of the workload across machines in the line, according to the capability of each, depends on an analysis of individual machine speed and behaviour, board and machine technologies, feeder requirements, pick and place speed per component, and the production process. The influence of these factors has also been proved in many real-life situations.

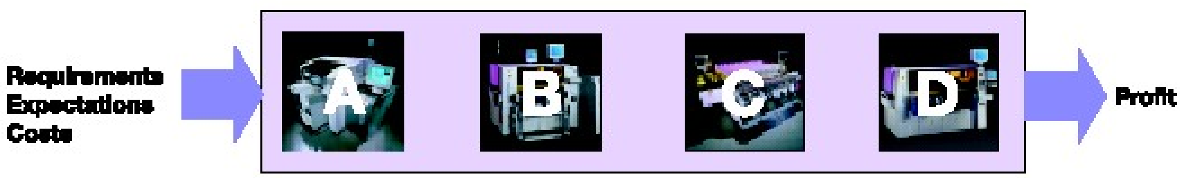
Preparation

Before a balance can be achieved it is important to start with the proper preparation. This involves the use of today's sophisticated line optimisation software, supported by training programmes which will give operators, supervisors and maintenance staff an enhanced insight into the processes.

However, this preparation goes further than programming and people. While perfect line balance may provide the best solution in high-volume and ultra-high volume manufacturing environments, the optimum solution in the mid-volume high-mix environment may actually demand that particular machines be 'de-tuned'. In the high- volume, low-mix line, perfect balance may reduce the cycle times between the fastest and 'slowest' machine in the line to less than three percent. In the mid-volume, high mix line, greater emphasis must be placed on minimising changeovers, for instance by grouping boards on the basis of volume requirement over a given time, size, or commonality of components.

The production 'engine'

The machines in the production line can be seen as a 'black box', with requirements, expectations and costs inputs and profit the output (Fig. 2a). The composition of the black

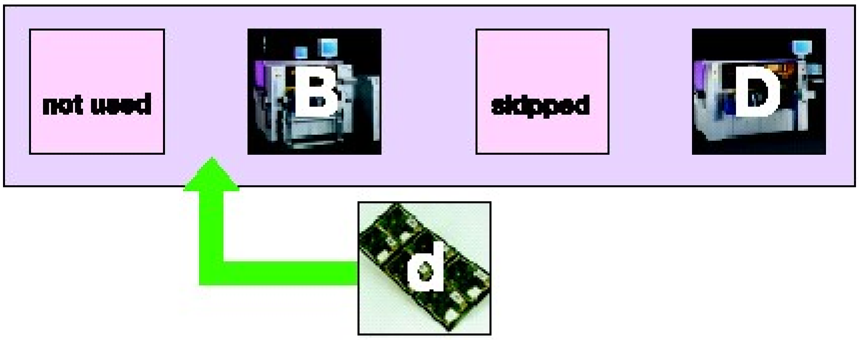


box fulfils requirements such as the number of products needed, quality, yield etcetera. In the following example several aspects of balancing the black box are reviewed.

Case 1: getting the configuration right at the start

Assuming that the black box has a layout for high-speed production, that is without changes, is produces products a, b and c with, say, 96 percent efficiency (ALL percentages in this discussion are fictitious). With overall factory efficiency assumed to be 85 percent, production efficiency will reduce to 85 percent (factory) x 96 percent (equipment) = 81.6 percent, but the required profit is achieved.

If product d is now introduced, the line configuration may change, to Fig. 2b.



Black box efficiency may still be 96 percent, but now maybe only 60 percent of the total black box capacity is used. The efficiency then reduces to 57.6 percent (60 percent of 96 percent). If now the factory efficiency is included, the overall efficiency drops to (85 percent factory x 57.6 percent equipment) or 49 percent.

The outcome is a very high cost for producing a single product, resulting in the yearly loss of a high percentage of the total capacity. Because overhead costs stay the same while efficiency reduces, there is a considerable reduction in profit. The lesson to be learnt is that failure to repeat line optimisation when a new product is introduced, or to configure a production line with future product in mind, has a substantial negative effect on line efficiency and profitability.

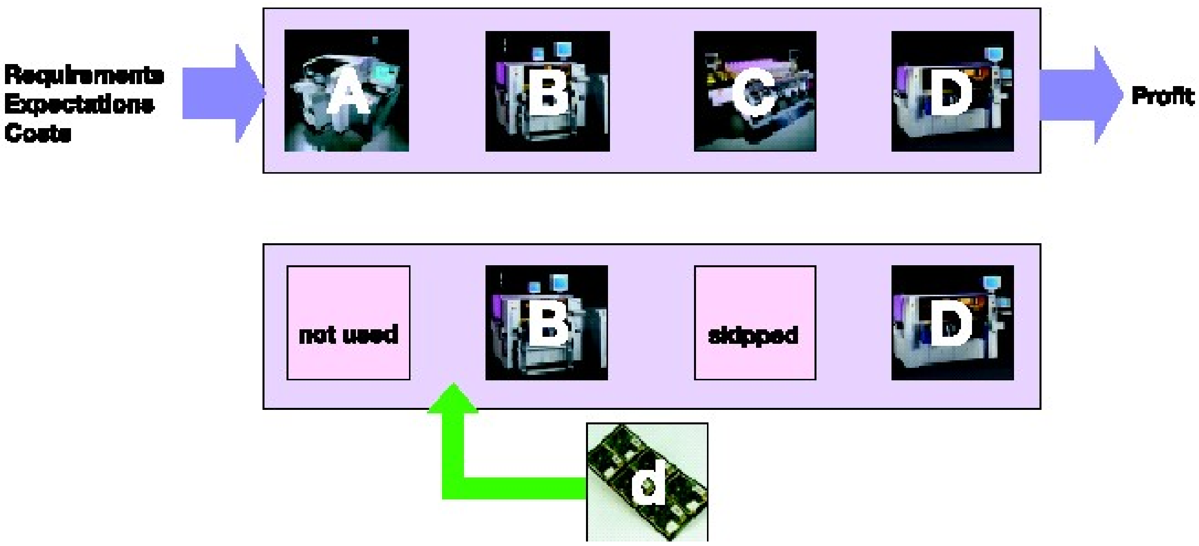
One of the solutions may well be to design a further unit into the line right from the start, helping to improve balance and deliver more products, and more profit, within a given time frame.

Case 2: balancing efficiencies

It may sometimes be assumed that the best solution is to optimise the line so that the fastest machine is working at 100 percent efficiency, but this is not necessarily the case. Suppose a line is set up so that unit A is working at 100 percent efficiency, as a result of which unit B is working at 99 percent, unit C at 98 percent, and unit D at only 72 percent. Overall line efficiency is 70 percent (100 x 85 x 85 x72). If the line is now balanced so that the fastest machine is working at only 90 percent efficiency but, as a result of optimisation, the other units are working at 95, 94 and 95 percent respectively, an efficiency improvement of over six percent is achieved. The lesson to be learnt from this is that the individual machine only makes a contribution to the total, but line balancing optimises the total to achieve a better profit/cost ratio.

Case 3: a slower machine on a faster line

Assume that in the line shown in Fig. 3a, machine A places 38k components, machine B

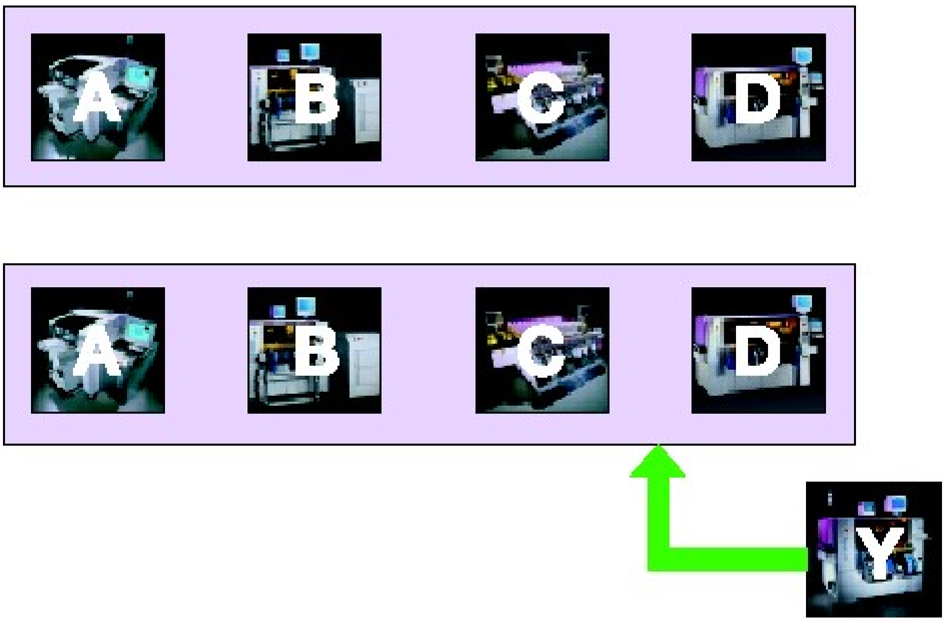


35k, machine C 2k and machine D 35k per hour so the line is capable of placing 110k components per hour. If the cycle time of machine A is 45 seconds, B is 37 seconds, C is 20 seconds and D is 37 seconds, the gross output of the black box will be 3600/45s (line cycle time is 45 seconds, and output is recalculated to this cycle time), that is 96.3k components an hour, or 80 products per hour.

Although the product cycle time of machine B is only 37 seconds, its actual output is less than the given 35k because the machine only gets a product each 45 seconds, the cycle time of machine A, resulting in 82% efficiency or 28.7k (35k x 0.82) components. A similar calculation can be made for machines C and D. The conclusion is that because the output of the line is determined by the slowest machine, A, the total line output is 'only' 80 products.

Suppose now that some components are shifted to machine C so that it places 3k components an hour, but with a cycle time of 40 seconds (total achievable line output is now 111k). While the average of machine C is worse, the overall performance may improve. Suppose that, because of the components shifted to machine C, cycle time for machine A improves to 40 seconds. Machine output stays the same, but cycle time for A and C improves while B and D stays as it is. Using the same calculation as above, the total number of components placed by the line improves to 105.75k, or a total of 90 (3600/40s) products can be made, an improvement of 11.25 percent.

Now an additional machine is added (Fig. 3b), resulting in the cycle time for all



other machines going to 33 seconds. In this time, the additional machine places 1k components, so the output of the line increases to112k. But the cycle time is much lower, resulting in 109 products per hour, an increase of yet another 21 percent (109/90 products) or, compared with the first example, 36 percent. Fig. 4 summarises the process. With this approach also, return on investment is an important factor.

Example 1	Example 2	Exampe 3
balancing not good	balancing reasonable	balancing good
slowest 45s	slowest 40s	slowest 33s
Fastest 20s	fastest 37s	fastest 33s
total performance 96.44k (100%)	total performance 105.75k (109.6%)	total performance 112k (116%)
80 products	90 products	109 products

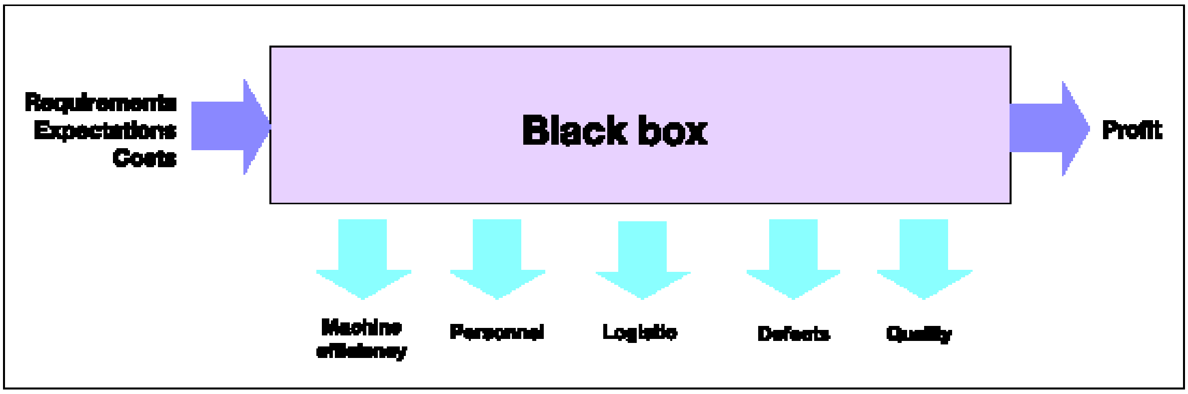
Case 4: less may be more

Imagine a production line containing five pick and place machines in line. Each machine has the capability to generate an output of, say, 20 000 components per hour. If it is assumed that each machine has a technical efficiency of 98 percent, the total technical efficiency of the five machines is 90.3 percent. This means that instead of the expected maximum output of 100k components, only 90k output is achieved. If an output of 95k components per hour is needed, at least one more pick and place machine must be added, but this will lower the overall efficiency.

Now imagine production running on a single pick and place machine with an output of 100k components per hour from the start. Now the required output can be achieved with a technical efficiency of only 95 percent, and the technical efficiency can be more easily achieved because only a single machine is involved. In addition, positive side-effects such as smaller footprint, fewer personnel, less maintenance, less component stock, and so on, come free of charge.

The importance of communication

Hi-tech manufacturing environments do not operate in a vacuum, and there are many influences on their efficiency (Fig. 5). For example, properly trained people are required to



run production efficiently. In practice, one operator may be sent on, for example, a production programming training course and may then be required to train 10 colleagues in-house, in a bid to save costs. The trained operator will only accurately impart a proportion of the knowledge gained on the original course, whether on the software or how the environment works. As a result, even at the outset, the line operators trained in-house may achieve only a fraction of possible line efficiency.

Over a short period of time, staff turnover means that the knowledge base, imperfect as it is, dwindles further. With no knowledge of the steps necessary to optimise production, new staff also pick up bad habits and efficiency progressively deteriorates. Within a year or two there may be no operators left who have been properly trained on the equipment. Line balance suffers, maintenance is not properly carried out, errors proliferate.

At first, it may not matter too much. Although not working at peak efficiency, the line may still be meeting production targets. When this ceases to be the case, alarm bells will ring. The line will be seen to be inefficient because it is producing less than it was guaranteed to produce. The truth is that through training and services not being optimised the line has always run inefficiently. Capacity which has never been developed could have been used to produce other products, or produce the given products in less time, saving considerable production costs. While the required output has been produced in three shifts, more efficient operation could have produced it in two, saving the cost of the third shift.

The production department can avoid the slippery slope to inefficiency through better communication between production and human resources management, leading to greater acceptance of the critical role of the operator in maximising output, and a more enlightened attitude towards training.

Payback on investment in training can be very rapid, as can investment in the specialist skills of the line equipment supplier. Assessment, advice and recommendation services can play a part, not just at commissioning but at regular intervals, resulting in continued stability of production. These services may well trigger a painful reappraisal of departmental interaction, leading to a complete culture change throughout the manufacturing organisation. But, in the wider scheme of things, selecting an equipment supplier which will provide support not just at equipment or line level, but at factory and even enterprise level, will deliver the most cost-effective route to the optimisation of manufacturing uptime, productivity and profitability.

For further information contact Ko Korteknie, Assembléon, Regional Centre Europe, Building HVM, PO Box 218, 5600 MD Eindhoven.
Telephone: +31 40 2766264. Fax: +31 40 2766541.

Captions

Fig. 1 It is important to have the complete company structure in balance

Fig. 2 The machines in the production line can be seen as a ‘black box’ fulfilling requirements such as the number of products needed, quality, and yield

Fig. 3 Individual machines only make a contribution to the total, but line balancing optimises the total to achieve a better profit/cost ratio

Fig. 4 Good balance improves overall line performance and generates more products and more profit

Fig. 5 There are many external influences on production line efficiency

ENDS

Assembléon's broad product range includes pick-and-place machinery and manufacturing support software for ultra-high volume continuous production through to medium-volume, high-mix batch production of electronic assemblies. Based on precision X-Y positioning platforms, instead of turret technology, and incorporating advanced self-calibrating vision systems, all its machines are among the best in achieving the highest placement accuracy, greatest component flexibility, and lowest cost-per-placement in their class. Support services include project management and consultancy, training, installation, maintenance, relocation and refurbishment. In addition to the company's headquarters and the International Competence Center in Eindhoven, the Netherlands, Assembléon operates its own sales and service organisations in over 42 different countries throughout the world. Through this global company network it guarantees its customers direct support 24 hours a day, 365 days a year.