Work performance measurement in the start of a new assembly line to achieve production target

Francesco Guerra
Università degli Studi di Brescia, Facoltà di Ingegneria, Dipartimento di Meccanica
Via Branze 38 - 25123 Brescia - Italy

Abstract
This paper considers the possible improvements brought about by a new assembly line for durable consumer goods for mass production, with particular attention given to start-up problems.
The technical and organisational requirements of the line are considered, with the line being set up as a homogeneous integrated group, with the release of worker groups without work constraint.
Its realisation depends upon the involvement of the employees and upon the constructive co-operation between the Company and the Unions following defined operational steps.
The results are sufficiently encouraging to suppose that, once the obvious personalisation has been taken into account, the path outlined here may have a general applicability.

Keywords
Work performance measurement, integrated group, group release and constraint, improvement, Company and Union structures.

1. Introduction

This paper intends to consider and comment upon the design aspects and applications of a new assembly line intended for incorporation into existing production workshops.
The existing plant production management is characterised by orderly regulations and organisational norms, with the subsequent restrictions in the planning, the start-up and operation of any new addition to the system.
In reality, the planning regulations are usually clear with regard to technical and theoretical aspects, but are frequently open to differing interpretations by the company and the union organisations once they become effective production and assembly lines and the real performance is called into question.
The situation is especially difficult when the performance regards the activities of the workers and requires innovative work methods or ones that are significantly different from those previously used.
The new assembly line is designed for the production of durable consumer goods, about a cubic metre in size, with the aim of assembling the finished product and the main preparation subgroups in an integrated way in order to reduce the lead time and improve conformity quality.
In the past, the main preparation subgroups were prepared off-line and were therefore not limited by line programming on account of medium-term stocks.
The organisational project also aims to create a line with a high hourly output, with subsequent cycle times of less than a minute, together with a new organisation of the labour force.
In fact, the organisation of the workforce foresees the possibility of workers being “freed” from the line itself, according to the rules and the practical definition of line release and constraint agreed between the company and the workers’ unions(1).
It is immediately apparent that the new line means new management situations for the preparation of materials, subgroups and the organisation of the assembly work.
The return on the investment and the consequent economic profitability clearly requires that the above-mentioned performance objectives be reached as a condition for undertaking the operation.
It should also be remembered that this operation represents an innovation compared to traditional methods and therefore can be seen as an example for future investments in new products and global output.

2. The Question

The problem consists of, firstly, a theoretical part and, subsequently, the practical application of the performance objectives.
The theoretical part is developed at the planning site, where a technical lay-out is prepared. This is integrated between the line and the preparation of the groups and a system for organising the work constraint and release, using appropriate line sections that fulfil the role of inter-operational release.
The theoretical phase is completed by simulating work equilibrium between the various workplaces, in order to validate the lay-out and the release zones.
The practical part consists in transferring the new work method to individual line workers, which means giving them training and helping them overcome the technical obstacles that derive from inevitable imprecision in the construction phase, as well as overcoming their more difficult mental resistance.

3. Theoretical and organisational requirements

The general lay-out of an integrated line is normally simple, since it is based on the proximity of the preparation of subgroups to the line and on normal connections based on balancing the activities within a single context and with the same rhythms of production.
However, resolving the question of the release of line workers is more complicated since it includes technical aspects of the plant and elements of the work organisation.
In theory, a "free line" (line without work constraint or with work release) is a line which allows individual operators to leave their workplace when they choose, for a pre-determined time that corresponds to the breaks set aside for physiological needs (e.g. 18 minutes per shift of 450 minutes) without compromising production.
By contrast, a "non-free" line is one that does not allow an individual worker to absent himself, except in cases of a collective stop or substitution of the worker in question by another worker.
The length of these said breaks is normally defined by contract and is a function of the workers (men, women), of the line rate (high, low, very low), production repetition, the complexity of the tasks, the expansion and greater detail of the phases, the balancing of each work station or ring of stations, individual balancing or that of the group, the feed characteristic of pieces on the line, the level of automation of certain stations, the physical and mental effort required, and other factors, too.
The combination of these various factors above can lead to numerous design solutions, with very varied investment costs, intended to achieve the organisational release.
The possible alternatives for introducing this line releasing are as follows (2):

1. creating sections of "breathing line" (inter-operational stock) between individual stations, with a duration equal to the maximum theoretical duration,
2. creating sections of breathing line between workstation groups, which are considered a single grouping, with a duration equal to the maximum theoretical duration,
3. creating sections of breathing line between groups of workstations, which are considered a single grouping, with a duration shorter than the maximum theoretical duration and, at the same time, sections of breathing line between individual stations with a duration shorter than the maximum.
4. Creating workstations outside the line, beside each workstation group in the line, with rotation of activities between those workers in the line and those outside, balanced within said group by an unsaturated state that enables it to substitute others when taking advantage of their release,
5. Combination of the above on the same line, in function of the characteristics of the activities in the various line sections.

In fact, it is useful if those who are going to use the line are involved at the planning stage, especially foremen and workers' representatives, who can give their approval to both the station lay-out and verify the existence of operative freeing.
Consequently, the best theoretical solution is that which involves all parties to be affected, such as the product designers, system designers, factory users, process managers, workers' representatives and the company management, and which is accepted after negotiation by all points of view.

4. Setting up the system

Once the preceding technical considerations have been made and the method chosen, it is possible to set up the system according to the various steps below (3) (4).
The lay-out of the line is seen as one main assembly flow, to which the preparations of three principal subgroups are connected upstream and to the side, with a balancing of the overall activity.
Figure 1 shows the technical scheme of the basic assembly line, with the flow of materials from left to right

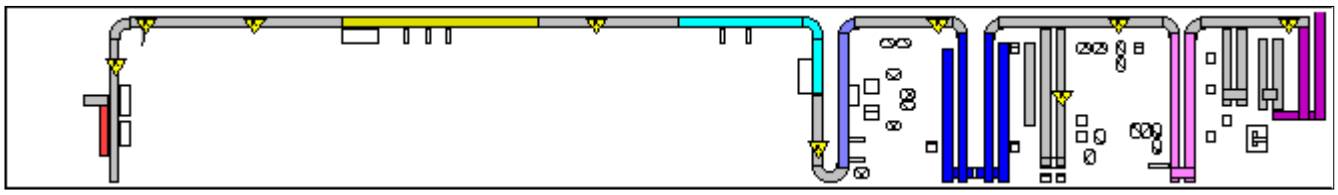

Figure 1, plan of the assembly line

Figure 2 shows the lay-out of the preparation of subgroup 1 at the line head and of the preparation subgroups A,B,C,D at the side of the line, in an independent set-up of the production.

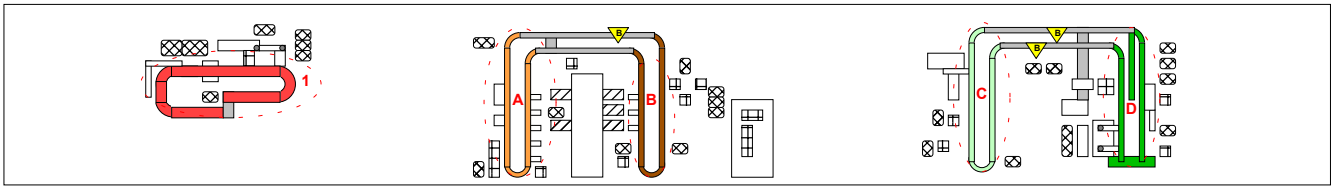

Figure 2, plan of the preparation of the subgroups outside the line

The preparation of subgroup 1, of subgroups A and B and of subgroups C and D may be set in independently from the line, in a specific area of the assembly department, with a slightly different lay-out that has stock points ready downstream from the preparation subgroups, or which is incorporated into the assembly line.
Figure 3 shows the situation in a dedicated department.

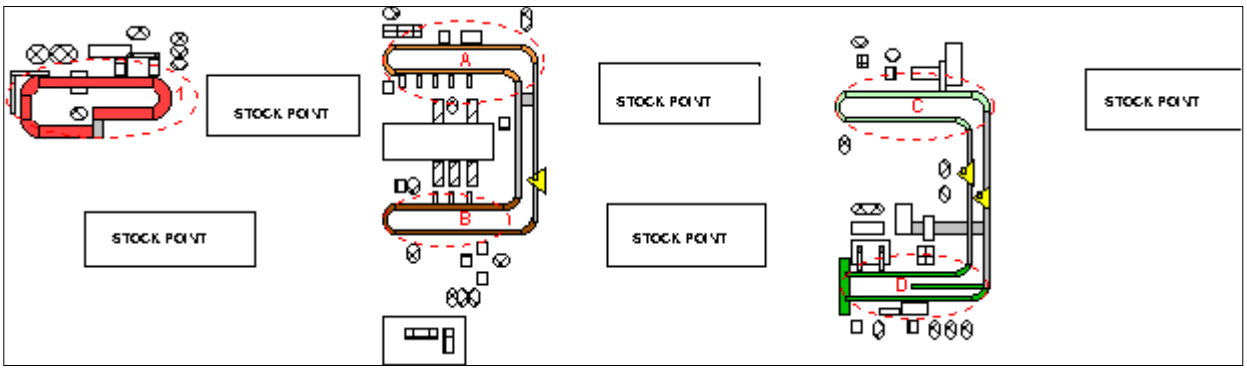

Figure 3, subgroups in a dedicated department

The chosen solution, though, is that which eliminates the stock points and integrates the preparation subgroups into the line, to give an integrated management of the assembly subgroups and of the assembly.
Figure 4 presents the lay-out necessary for that purpose.

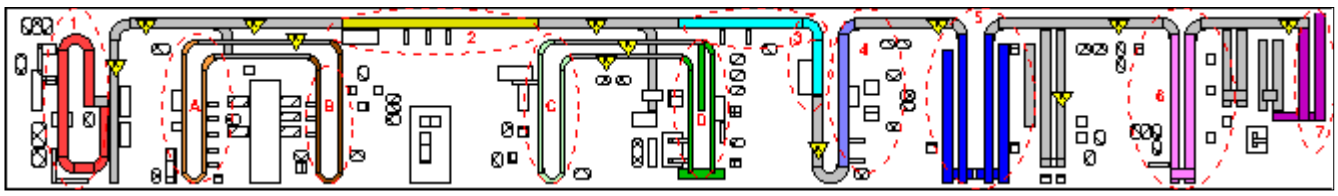

Figure 4, lay-out of the integrated line

It is immediately clear how the lay-out in figure 4 means that the production line has its own evaluation and handling, favouring the creation of a factory within a factory (a plant within a plant).
The line, therefore, is a homogeneous production group (also known as Elementary Technical Unit), with its own performance data clearly measured, such as the comparison between the finished products and the resources directly used (5).
The lay-out above takes into account the aim of creating a free line that exploits the stops-breaks at an individual level, these being decided by the worker himself.
The various alternatives also included a line with several compromise solutions, reflecting certain technical and organisational factors, namely:

1. the releasing is intended to cover homogeneous groups of workstations, up to a maximum of eight workplaces in the worst hypothesis,
2. the organisation of the work within the individual groups is such as to be able to define a conformity quality control within them, so that the production feed can proceed free of defects,
3. the organisation of the work within each individual group is, at the workers' choice, in total or partial rings and across various workstations, according to necessity,
4. the theoretical pauses are taken in two different moments of the working day, one before lunch and one after,
5. the result of all the above is the possibility to have an inter-operational breathing space that is shorter than the theoretical total of the different groups.

Taking these considerations into account, figure 5 shows the organisational groups of the line, numbered from 1 to 7, integrated with the preparation subgroups A,B,C,D, which are connected to the line.

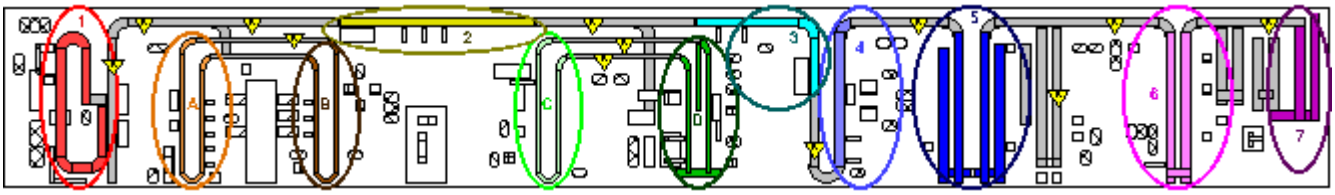

Figure 5, the subdivision of groups in the line

In figure 5, between the preparation of the subgroups and the line and between the different groups in the line, there are sections of the line indicated by a triangle with the letter B.
These line sections have a length (L), at least equal to the theoretical pause (P), dividing the cycle rate (t_c), multiplying the minimum length of travel of a piece (l_s), increased by several lengths α (minimum space, normally equal to ls, before the first workstation in the group n + 1), β (minimum space, normally equal to ls after the last workstation in group n), χ (space that takes into account eventual difficulties in the line, the complexity of the previous and successive phases and the number of workers in groups n and n + 1, normally equal to 2 or 3 l_s).
The minimum length of the line sections (B) is, therefore, as follows:

$$L = (P/t_c) \times l_s + \alpha + \beta + \chi$$

It should be noted that the organisational set-up balances the line by groups and not by individual workstations, with a significant improvement in the unsaturated performance of workers.

5. The organisational set-up

The organisational characteristics of the line make it indispensable that the line workers be involved (6) (7). Workers' representatives have already been involved in drawing up the plans for the line, but, whilst this is normally a necessary condition it is not sufficient, since it is the line workers who make the products and need to be trained.
The organisational set-up relies on several fundamentals:

1. preparing a balance in the line, as if the line were obliged to carry out an initial start-up training,
2. setting the initial start-up training with reasonable higher and declared form of unsaturated work balance of the line,
3. getting ready a multifunctional matrix for the workers, in order to monitor the training during the various phases,

4. continuing the initial start-up of the non-free line with a constant reduction in the unsaturated status,
5. constantly monitoring the line performance,
6. once having reached the objective of the non-free line, setting the start-up of the free line, adequately balancing the groups internally, but with the possibility of restorers outside the line,
7. reducing the number of out of line restorers to permit the non-free line to settle,
8. activating a flexible team of technicians alongside, with funds already available, to carry out operations requested by the workers during the start-up phase (for example, additional equipment, extending the breathing sections in line B, pre-assemblage benches beside the line, etc.),
9. constant updating and checking of the objectives of the free line,
10. approval jointly agreed by the company and unions of the results and the performance conditions prior to handing over to the normal factory management.

As far as method is concerned, the management uses the normal company procedures, introducing only a few specific checks and activating the appropriate "Joint Technical Committees" of the company and unions, which are foreseen by the collective company negotiating.
The organisational set-up requires a constant performance measurement during the start-up phase.

6. Measuring performance

Measuring the performance is based on the comparison between what is produced and the resources used, and on the respect for programming and start-up times and costs.
The essential elements are represented by the line scheduling, in such a way as to meet the balancing needs of the workers.
Matching the scheduling to the resources is taken for granted since it represents a company choice.
The most interesting factor is the measurement of the production results against the quantity of resources used, which is often a source of argument.
The measurement is based upon the relationship between the quantities produced and those planned, on the relationship between the increase in value (standard time) of what is produced and the presence of workers in the line and outside it, on the reasons for inefficiency and loss of personnel, on the documentation of personnel training for their individual duties within the groups.
Comparing the scheduled output with that effectively produced is a classic line report, which is normally obtained at the expense of resources used, whether during the time the line is operational or outside that time.
Additional activities during normal work-time and outside it have to be kept under control by a check that is extra to the normal line accounting, with additional details that separate the normal delays of materials from problems with the line.
It is important that this check be done together with workers' representatives and that it be made public.
The most critical factor is usually the verifying of the operators' training, which represents the major strength or weakness of the whole start-up.
The multifunctional matrix inside the group is the basis for assessing the progress in training about the product and the new organisation.
Once the training has been developed, it is essential to prepare rotations between the workers in the various groups in order to balance up the human resources as well as possible.
At this point, the indices of line efficiency should be available, as well as the target, and the new organisation can be approved.
The line in question could also be arranged so as to link the workers' retribution to the line performance, as part of the traditional contracting of premiums for results or collective participation (8).

7. The results

In the case in question, the following results are the most important:
1. the investment costs of the free and integrated line are noticeably higher than those of a non-free line,
2. the product cost is in line with the target,
3. the planning and setting up time for the line is eight months, from a technical point of view,
4. the organisational set-up time was ten months, with numerous adjustment operations to the intermediate breathing sections between the groups and verifying of personnel training,

5. despite the involvement of workers' organisations from the beginning, the application phase had to overcome numerous difficulties from the Unions,
6. the constant measurement of performance and the separation of the causes of inefficiency on the line was an important solution, since it led to precise discussions rather than wasting time in general talks,
7. the conclusion and the attainment of results was satisfactorily confirmed by all parties after a difficult union negotiation.

8. Conclusions

Measuring performance is an element in managing the start-up of an industrial plant, especially where there are organisational innovations.
Such organisational innovations often depend on human involvement and attain their results thanks to the participation of all parties in the improvement.
Both the theoretical and the practical case emphasise that the constant measurement of performance makes it possible to resolve the numerous operational problems inherent in a new assembly line in a technical and documented way.
Managing the line with a free model of grouped workers gives a better performance in quantitative terms than a non-free model, without considering the greater participation of the workers, who can, in theory, manage their own work time better.
Therefore, this method for attaining performance goals can be used, with the necessary specific adjustments, in a general context for investments in assembly lines with high work content.

9. References

1. Guerra F., Braga G. "Manuale per la comprensione degli elementi base per i tempi e metodi di Lavoro, Vigenti metodologie per la misurazione della prestazione di lavoro" - Edizioni della Gifram per Electrolux - Zanussi, Roncadelle - Pordenone, 2002
2. Guerra F. "Bilanciamento del lavoro a gruppi di stazioni negli impianti manifatturieri" - XXVI Convegno ANIMP, pag 449-467, Ischia 1999
3. Guerra F., Antonioli A., Braga G. "Choice of model for lay-out reorganisation" - Logistics in the Information age, ISBN 88-86281-37-4 pag. 821-826, Firenze, july 1999
4. Guerra F., Antonioli A., Pizzichillo C., "Application methods in the change-over from job shop to flow shop" - The 15th international Conference on Production research, pag. 1271-1274, ISBN 1-874653-56-9, Limerick 1999
5. Guerra F., Riccò N. "Integrated Production Groups in lean organisation" - The 15th international Conference on Production research, pag. 1283-1286, ISBN 1-874653-56-9, Limerick 1999
6. Guerra F. "Polifunzionalità, prestazioni e potenzialità prestative del personale operativo negli impianti industriali" - II Congresso Europeo di Igiene Industriale, pag. 223-227, ISBn 88-7963-103-9, Maugeri Foundation Books, Pavia, 2000
7. Guerra F. "L'evoluzione delle mansioni di lavoro nelle attività manifatturiere" - Giornale Italiano di Medicina del Lavoro ed Ergonomia, pag 160-171, ISSN 0391-9889, Pavia 2001
8. Guerra F., Braga G., Mazzola C. "Organisational changes and production performances linked to collective economic agreements" - The 15th international Conference on Production research, pag. 717-720, ISBN 1-874653-56-9, Limerick 1999