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GANTT PERFORMANCE INDEX (GPI)

Experimental method for calculating a site organization performance index. Decreasing the time spent on the construction site, downtime durations and consequently increasing the company's profit, are the objectives to which the metrics described here are aimed, which the author calls “Gantt Performance Index”. Constraints and problems of interference of activities in construction projects, in the planning of which fundamental element remains work safety.

Construction site “performance.”

In physics, referring to thermal machines, efficiency is defined as the ratio of work accomplished to energy supplied. Just as in the thermal machine the input energy is not fully utilized to produce work, so the energy of the workers' teams does not usually cover the maximum amount that can be absorbed by the availability of space and time on the construction site.

Optimizing processes and decreasing the costs involved in making any product are the basis of our economic system, and for example in the field of engineering the optimization of structures to be calculated with respect to acting loads is the order of the day and fundamental to the proper planning of a project. As long as we consider variables that are placed in analytical relation to each other, everything “adds up,” different is the case when we try to make controllable a process, albeit logical, highly random, such as the organization of a construction site, since many variables and unforeseen events come into play (from weather to unforeseen technical contingencies in general), are not always controllable by man.

Therefore, to optimize the management of the construction site, in addition to foresight, it is required that the logical planning and control process that regulates the individual operations and puts them in operation with each other produces as a product the maximum that can be obtained from the construction site itself in terms of result/effort ratio (the latter being expressed in man-days or similar). On the basis of obtaining the same outcome value, we can also consider how we can use as little energy (resources/money) as possible, and how such a method can help us rationalize the process as much as possible.

Site installation plan.

By putting in writing on the calendar the durations and relationships of the operations we should carry out at the construction site, one already has a clear understanding of the succession of these operations and the links between them (typical start-to-end, start-to-start, end-to-end), but how confident can one be that the logical process and succession of operations is the optimal one, i.e., the maximum achievable related to that specific context?

First of all, one should analyze the available space and make sure that the “Site Installation Plan” (PIC) has considered adequately sized storage areas and transit routes inside the site. This aspect is very important because it conditions the logistics of supplying subcontractors, whose work is strongly

conditioned both by the amount of material to be laid on the site and by the safety design and collective protection systems put in place.

Next, one should analyze the number of lifting equipment that will be available in order to be able to carry the materials intended for laying by individual subcontractors to height.

There are in fact so many elements and variables to be considered for a correct treatment of the problem that we will address one step at a time.

Let us therefore focus on the object of this article: the presentation of a method that can help rationalize the spaces, times and relationships between the teams that are managed daily during the work and that can give us a yardstick with respect to maximizing the process in terms of result/effort. In the context at hand, the main necessity in identifying a good Gantt is first and foremost the concept of complying with the requirements that are described in the Safety and Coordination Plan (PSC), the document prepared by the safety coordinator at the construction site and aimed at organizing the companies present, minimizing the risk of accidents during the work.

In fact, each team may have assessed the risks derived from its own work, without having considered the risks of work that took place previously or will have to take place later, as well as may become interfering with its own activity.

We will therefore start from the principle that two teams related to different workings cannot work simultaneously

within the same place or “minimum space” of work, as this would contribute to the increased risk of accidents.

Starting from this assumption, the following steps will be taken.

1. Division of the building into “n” workplaces (CLE)

The geometry of the building is analyzed and an attempt will be made to divide it into a well-defined number of distinct workplaces that will be occupied by a single piece of workmanship at a time and by components of the same team.

The fact that we refer to components of the same team is a consequence of the fact that they (or their supervisors) themselves (or their managers) have assessed the safety risks arising from the specific workmanship, and therefore do not have to interface with risks arising from workmanship other than their own. The maximum number of workplaces will depend on the size of the site and their number will be limited by the size of the individual “elementary work cell” (CLE).

Beyond a certain limit of division into such cells, not only is it no longer possible to work there, but there are also no additional benefits that can significantly improve the overall duration of work (Fig. 1, Multi-story type building section).

2. Scheduling of resources and identification of incompressible processing of maximum duration.

The second operation will consist of the scheduling activity, evaluating each WBE' (Work Breakdown Element) present at the elementary work cell and identifying the WBE that is “incompressible” and that is, has maximum duration. This is crucial because the duration of the incompressible

workmanship will generally also affect the timing of subsequent workings at the other workplaces. A typical example of incompressible processing is the pouring of concrete screeds or all those typical site operations that require a well-determined curing time.

In this case we will speak of “overlapping incompressible processing” since the casting will occupy only 1 day while in the 15 days required for its curing the same operation can be carried out in other elementary cells. In the case where the duration of the operation is characterized by the continuous presence of workers, on the other hand, it will be called “non-overlapping incompressible processing.” The concept behind this definition lies in the fact that in order to seek the minimum amount of resources used, one cannot overlap the same processing on two different workplaces, since multiple teams would have to be used for the same WBE.

3. Gantt chart construction and rescheduling of WBEs to eliminate interference and inactivity.. The third operation is to distribute the WBEs to the CLEs into which the building has been divided by constructing the corresponding Gantt chart.

At this level, care should be taken to eliminate downtime as much as possible by rescheduling the WBEs if necessary according to the dependency ratios

End-to-Start both with the same operation performed on another CLE and with the next operation, so as to have as constant and uninterrupted activity as possible in all identified cells.

This method is schematized in the linear flow-chart shown in Fig. 2 (in which the possible reiterations are not shown for simplicity).

Example

Consider, for example, a 4-story building and assume that one has already built the so-called “out-of-water rough”' and that all around the building one has free space.

The prospective state, related to the work inherent in the construction of the rough structure (either in the case of traditional construction or using prefabricated panels) means that one needs the total availability of the lifting means, which becomes a critical resource as one cannot start other work unless he has another means available. Moreover, because of the danger of material falling from above, and the durability of the materials below, the operation of erecting the structure up to the out-of-water must necessarily in most cases remain the only one present, along with the erection of the perimeter scaffolding. Starting from the “raw out-of-water” state of affairs, we begin the type of analysis indicated above. As shown in Figure 1, the 4-story building will have 5 working levels (Ground Floor and the 4 Floors) and 2 working environments (Indoor and Outdoor). So at first analysis, one might consider having 10 different CLEs available, in which 10 teams can work simultaneously. However, this consideration introduces an initial logical error, since the work must be carried out in each CLE successively to each other, following a predetermined order (as understood below).

All'interno dell'edificio si avrà la seguente sequenza più o meno condivisibile, che può dipendere anche dalla stagione in essere (estate o inverno).

Operations inside the building:

1) laying the plumbing and electrical systems to the ground and tracing the bricks;

2) laying of the infill screed;

3) laying of underfloor heating;

4) laying of underfloor screeds;

5) construction of interior partitions - Window installation;

6) plastering;

7) laying of floors;

8) laying of sanitary ware and accessories

9) painting;

10) installation of interior doors.

Outside the building the operations will be as follows and are independent of those inside except, only for sharing the means of lifting materials at height.

Operations outside the building:

1) installation of the coat;

2) realization of the plaster;

3) realization of the sheet metal work;

4) dismantling of scaffolding and loading decks;

5) exterior accommodation.

Reasoning therefore on the calculation of the maximum number of operations that can be carried out at the same time, one can arrive at buying one for each level inside the building, a total of 5, and 2 at the most outside, since by doing the so-called "coat" on the upper floors one can start the activity of shaving (connectable to the above activity of "Realization of plaster") on the lower floors, consequently advancing with two teams at the same time.

The difference from the initial estimate is derived as follows: while indoors one is constrained by the number of CLEs and the spaces physically divided by the raw structures (floors and walls) of the building itself, outdoors one is limited by the types of workings and their duration.

For this reason, the most overlapping workings on the exterior are those that can coexist on different floors both for similar duration and for logistical reasons, such as the laying of the coat and the plastering.

The laying of guttering (gutters, sheet metal elements, etc.) in particular, being, moreover, very short compared to the previous two, must necessarily be carried out after the first two are completed, as its duration would not allow for a congruous or profitable overlap. The conclusion is that the maximum number of operations we could consider at the same time is 7 in total (and not 10 as initially assumed). We have therefore identified the maximum number of CLEs into which the work site can be divided.

Calculation of site yield.

The concept of yield is associated as mentioned with the ratio of Work accomplished to Energy expended. The number 7 ideally represents in the present example the maximum energy that can be

absorbed by the system, i.e., the maximum number of overlaps possible for the conformation of the work, at a given time or interval of engagement. Based on this figure, the preliminary Gantt can be defined, mentally going over the succession of operations, but paying attention to the type of overlap between internal and external workings.

With the help of the software programs that manage the construction of the Gantt, labels can be applied to the task bars, so as to visualize whether the processing is internal or external and at what level of work (e.g., INT Level 1 or EXT Level 4); in this way, the degree of overlap and which points of the building are affected by simultaneous processing can be visualized. Having verified that the speed of the various workings corresponds with the technical possibilities of the subcontractor and that the activities are congruent with the logistical possibilities of the storage spaces within the building site, the maximum number of simultaneously present workings per week can be counted.

On the basis of these, the weekly "yield" of the organization fielded can be defined as the ratio of the maximum number of simultaneous workings to the maximum number of total workings. An example of application is given in the box in Tab.1. Similar definitions could be given for different time intervals (e.g., per single day).

One can then derive the graph of the effort required, which indicates the trend of work that can be accomplished, and in particular its intensification in terms of the maximum number of crews simultaneously on the site (Fig. 4). The more time-constrained and narrow this curve is, the more it will generally mean that space is being optimized to do the same work. It immediately jumps out, for example, in the proposed diagram the greatest number of overlaps (simultaneous activities) between weeks 8 and 10, the period in which the presence of men on the construction site peaks.

As noted, such a diagram lends itself to a quadratic interpolation representing a characteristic convex load curve, characteristic in different types of projects about the trend of committed resources over time (as shown in the diagram in Fig. 5 below). In this, the aforementioned curve represents the nominal schedule utilization of the construction site (whose total duration is 14 weeks) and the discrete trend represents the number of workings actually planned or recorded in the final record (whose total duration is 21 weeks). Another issue that might arise at the planning stage is how to reconcile the number of simultaneous workers, including the workers from different subcontractors, with other construction resources, such as the presence of only one hoisting vehicle.

Usually, in fact, the vehicle is needed by the subcontractor for 1 hour maximum per day in case, for example, most of the work is involved in the laying activities, and it will be necessary to establish shifts in which each subcontractor can be able to carry the materials he or she will need on the same day, or rather in the next few days, so as to maximize the transport at height with as much material as possible and needed on the different floors. Having obtained the weekly yields, we now define the worksite work index in numbers only. For this purpose we use a weighted average value index of the yields related to the total time T of commitment of the worksite, through the following formula, which we will refer to here as the Gantt Performance Index (GPI).

Example of using the index in the bidding process.

The value of the proposed index can be particularly useful in the bidding phase, to compare one's Gantt with the preliminary one presented by the contracting station, against which the potential supplier will have to propose improved project solutions and at the same time provide the summary figure of the improvement in site management, as well as in compliance with the constraints imposed. In fact, the time improvement can obtain an advantage in the tender score, where it is required, for example, that a maximum number of days be saved, justifying and demonstrating with a Gantt the best-case working hypothesis.

The index obtained by this method completes the information, as with a simple index it leads the participating company to declare that it has improved the performance of the worksite by a certain percentage ratio compared to the tender base, indicating not only the time savings but also the different concentration or optimization of work over time. This method was specifically tested by us in a tender where 90 days of work were required to be saved over 78 weeks, with a relative improvement of 16 percent (90/ (78*7) = 0.16). In reality, the increase should have also taken into account the distribution of work over time and consequently assessed the simultaneity of more or less concentrated work.

The result of the study led to an improvement of the proposed GPI over the tender basis not by 16% but by 63%, thus increasing the feeling of the contracting station about the good execution of the chrono-logistical study of the construction site. The summary of that study is shown in Fig. 6.

Study of alternative plans.

As a further application, the results of an example carried out on a typical construction site are proposed, in which it is intended to demonstrate how the GPI and duration of workings can vary as a function of the number of elementary cells (CLEs) into which the spaces are divided, while keeping the workforce of each individual WBE constant.

Assume, for example, a division of the same physical project scope into 2 CLEs and then into 3, 4 and 6 by proportionally dividing the workings according to the number of elementary cells. For example, it is shown that a processing that lasts 14 days for 2 CLEs, in the case of dividing the building into 2 parts, will last

8 days in the case of dividing the same building into 3 CLEs, and so on for larger divisions. In the case in example, 6 different WBEs with characteristic durations were assumed and applied to the various hypotheses of division into CLEs; in addition, two cases were assumed, in the presence of overlapping and non-overlapping incompressible workings. In the case of the presence of non-overlapping incompressible workings, these WBEs were all linked by End-to-Start (FI) links with critical paths free from any kind of advance (lead) both between them within each individual CLE and between different CLEs.

In the case of the presence of overlapping incompressible workings, these WBEs were all bound by FI bonds with critical path only with respect to the single elementary cell, while accepting the early onset of a WBE in the other CLEs. The results were then obtained as in the following graphs (Fig. 7), as well as summarized in the table, concerning the respective GPI values calculated in the different cases (Tab. 2).

It should be noted that GPI is an index related to weekly performance over time with the following meaning: if the nominal maximum number of overlapping workings increases, the value of the index will decrease, and if it decreases faster than the time being gained, the more it will decrease in marginal terms the overall performance of the worksite. Moreover, the value of GPI as defined before should not be taken as an absolute value, but as a comparison value between the Gantt, in the original work hypothesis, and the reworked or eventually optimized one. As it is observed, in the case of overlapping incompressible work, between the division into 2 and 6 CLEs there is a significant decrease in the GPI (29%) and in the duration time of the construction site (53%); therefore, provided there is a lower organizational performance, as defined before, one can make better use of the available space and concentrate more parallel work on the overlapping WBEs, decreasing the overall time of completion.

In the case of non-overlapping incompressible workings, as the number of cells increases, the results show a greater decrease in both GPI (44 percent) and site duration time (64 percent).

These results, in line with intuition at least as far as the effect on time is concerned, should, however, be compared with those of an economic nature and related costs, further evaluation of which could make one identify the best compromise solution of the final planning point, also in relation to other trade-off factors and the priority objectives of the project. In case, for example, there are multiple subcontractors, the relative availability and occupancy of the teams should be reconciled with the overall site organization.

It is evident to emphasize how we cannot make an a priori general argument about what is the maximum value of divisions of our building or work site and organization to arrive at the optimal result, but rather the importance of the method of how to get there.

Conclusion.

The complexity and multiplicity of site types means that no single, absolute solution can be found in optimizing their management, but rather to propose a method of approach that can, among other things, provide a concise evaluation of results. The GPI index described here proposes to give guidance on chrono-logistic optimization of the site and with the indicated flow of planning activities, provide an analysis of the performance of a construction contract in the planning phase, preceding and complementing the best-known economic control indices typical of project management based on the Earned Value Method (Cost Performance Index and Schedule Performance Index).

The method presented is also intended to take on board the specific evaluations that occur in the case in question, such as the constraints of interference between activities, having an impact on work safety, and those of a logistical nature (available space and means), identifying the maximum number of simultaneous workings possible at the site and describing their progress by means of the Gantt and the related workload (effort) curve. Although referring to the Gantt, on the basis of which it was also developed in relation to the requirements of common use of the same tool, the same index could more generally apply to the concept of a project plan or baseline, for the setting up of a job order and the chrono-logistical verification of the site organization, from which important aspects of a technical-economic nature derive.

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