Programming And Load Balancing For The Development Of The Multifamily Building - Lima, Peru 2020

Robert Calvoa, Doris Esenarrob, Franz Hernandezc, Lorena Velad, Raul Mendezc

a-d, 5EUPG Graduate School Federico Villarreal University – UNFV
b, c, Federico Villalreal National University, Lima-Peru.
Email: a20200051212@unfv.edu.pe, bdesenarro@unfv.edu.pe, c2020005203@unfv.edu.pe, d2020005429@unfv.edu.pe, ermendez@unfv.edu.pe

Article History: Received: 10 November 2020; Revised 12 January 2021 Accepted: 27 January 2021; Published online: 5 April 2021

Abstract: The objective of this research is to show the production management in the construction of a multifamily building in Lima - Peru, it is worth mentioning that the main problem is that the companies do not adequately plan the optimal use of resources, the plan of attack of work, the sequence of activities through a correct design of production batch and sizing of crews, which are decisive during the execution of the work. The methodology used in this context is load and crew balancing. This allows us to manage resources and work scheduling, resulting in 100% efficiency. In conclusion, we can say that companies must maintain a correct control of their resources in order to achieve their schedules.

Keywords: y

1. Introduction

The construction sector has continuously been syndicated to imperfect performance. In general, the impression is that construction is a sector of low productivity and dubious quality given the lack of specialization of workers and professionals in the sector, many of the problems mentioned above are generated due to the lack of planning of the works, since the problems are solved as they appear. Although it is true that there are inconveniences that appear unexpectedly, many of the obstacles to the normal production of a task are predictable. Some professionals believe that the results of their design and construction management work had been completed within budget. However, these data are followed by those who completed their projects in the construction phase more than 3% over budget in the design phase, under 3%. In terms of time, this was not good in the construction phase, with most finishing less than 15 days behind schedule. [1].

Nowadays, construction companies not only offer lower cost works, but also quality, safety and time. Therefore, they seek to optimize their work times, generating efficiency and profit for the company. This uncontrolled number of projects has a main "defect" that comes to light and is incredibly costly: the waste or losses that are generated in the construction stage of these projects. [2]. These companies have been implementing the Lean Construction philosophy, achieving favorable results in terms of profit margins, productivity, labor efficiency and safety [3].

The traditional construction planning is based on making the work plan with scheduled dates, visualizing the duration of the items, as well as the total time of execution of the work. However, the optimal use of resources, the work attack plan, the sequence of activities through a correct design of production batch and sizing of crews, which are decisive during the execution of the work, are not adequately planned [4], which is why this article aims to show how production could be managed in the construction of a multifamily building in Lima - Peru. The essence of the system is to work to increase the reliability of the planning. The ultimate planner is the one who finally defines what will be done and who will do the work. The role of ultimate planner can be held by foremen, construction managers, supervisors, subcontractors, site managers and others. [5]

2. Method

Study area

The study was conducted in Peru, in the city of metropolitan Lima. (Figure 1).
Figure 1. Localización de área de estudio.

Figure 1 shows the location of the study area, framed in the department of Lima

Type of research
The quantitative research will analyze the facts prior to and during the execution of the multifamily buildings, for this the experience must be taken into account and thus analyze correctly and concisely in our study. Likewise, the personnel resources to be used will be analyzed. From the information, the results will be obtained to make the corresponding decisions. [6]

3. Procedure

| Table No.1. Metrization per unit of element |
|-------------------------------------------|
| METERING PER UNIT OF ELEMENT               |
| ELEMENT  | NAME | STEEL (kg) | ENCOUNTERED (m²) | CONCRETE (m³) |
|----------|------|------------|------------------|---------------|
| Verticals | C1   | 1000.00    | 40.00            | 10.00         |
| Verticals | C2   | 500.00     | 20.00            | 5.00          |
| Verticals | C3   | 750.00     | 30.00            | 7.50          |
| Horizontals | P1 | 1250.00    | 30.00            | 7.00          |
| Horizontals | P2 | 1500.00    | 40.00            | 9.00          |
| Horizontals | P3 | 1000.00    | 20.00            | 5.00          |

Table No.1 shows the corresponding metrics for the different elements used in the project.
For practical purposes, only the vertical and horizontal items will be taken as shown in Figure 2 and 3.

Figure 4. Vertical sectorization plan

In Figure 4 and 5 shows the metrics, we proceed to sectorize the work area which consists of dividing a task or activity of the work in sectors, a small part of the total task should be included and in turn should include an approximately equal metric trying to balance the loads as shown. [7]

Sectoring in a correct way allows us to obtain greater efficiency, improve control and maximize production capacity.

Table N°2. Vertical metering

| SECTOR | ELEM | NAME | TOTAL METER STEEL (Kg) | TOTAL FORMWORK LENGTH (m2) | TOTAL CONCRETE THICKNESS (m3) |
|--------|------|------|------------------------|-----------------------------|-------------------------------|
Table N°2 below shows the vertical element metrics according to the sectorization carried out.

### Table N°3. Horizontal metering

**METERING OF HORIZONTALS**

| SECTOR | ELEMENT | NAME | TOTAL METER STEEL (Kg) | TOTAL FORMWORK LENGTH (m2) | TOTAL CONCRETE THICKNESS (m3) |
|--------|---------|------|------------------------|----------------------------|-------------------------------|
| Secto r 01 | Vertical s | 2 | 0.00 | 3000.00 | 120.00 | 30.00 |
| Secto r 02 | Vertical s | 0 | 4.00 | 3000.00 | 120.00 | 30.00 |
| Secto r 03 | Vertical s | 0 | 4.00 | 3000.00 | 120.00 | 30.00 |
| Secto r 04 | Vertical s | 0 | 4.00 | 3000.00 | 120.00 | 30.00 |
| Secto r 05 | Vertical s | 2 | 2.00 | 3000.00 | 120.00 | 30.00 |
| **TOTAL** | | 4 | 1 | 15000.00 | 600.00 | 150.00 |

Table N°3 shows the horizontal elements metrics according to the sectorization carried out.

### Table N°4. Load balancing per sector unit

| Activity | Quantity | Unit | Rend | Unit | HH | crew |
|----------|----------|------|------|------|----|------|
| Vertical Steel | 300 | kg | 0.030 | hh/kg | 90 | 11.25 |
| Vertical Formwork | 120 | m2 | 0.850 | hh/m2 | 102 | 12.75 |
| Vertical Concrete | 30 | m3 | 1.000 | hh/m3 | 30 | 3.75 |
| Horizontal Formwork | 120 | m2 | 1.200 | hh/m2 | 144 | 18 |
| Horizontal Steel | 500 | kg | 0.050 | hh/kg | 250 | 31.25 |
| Horizontal Concrete | 28 | m3 | 1.000 | hh/m3 | 28 | 3.5 |
| **Totals** | | | | | 644 | 80.5 |

Table N°4 shows the yield that would be obtained for each sector, we will take one and with the support of the Unit Price Analyses (APUS) we will determine the yield that would be obtained for each sector. [8]
Tabla N°5. General load balancing

| Activity       | quantity | Unit | Rend  | Unit | HH  | crew |
|----------------|----------|------|-------|------|------|------|
| Vertical Steel | 1500     | kg   | 0.030 | hh/kg| 450  | 56.25|
| Vertical Formwork | 600.0  | m2   | 0.850 | hh/m2| 510  | 63.75|
| Vertical Concrete | 150.0  | m3   | 1.000 | hh/m3| 150  | 18.75|
| Horizontal Formwork | 600.0  | m2   | 1.200 | hh/m2| 720  | 90   |
| Horizontal Steel | 2500     | kg   | 0.050 | hh/kg| 1250 | 156.25|
| Horizontal Concrete | 140.0  | m3   | 1.000 | hh/m3| 140  | 17.5 |

Totals                                                3220  402.5

Table 5 shows the load balancing for a sector and for the entire project. The load balancing should be according to the specific activity to be performed

Tabla N°6. LookAhead

| Activity       | D1 | D2 | D3 | D4 | D5 | D6 |
|----------------|----|----|----|----|----|----|
| Vertical Steel |    | X  |    |    |    |    |
| Vertical Formwork | X |
| Vertical Concrete |  X |
| Horizontal Formwork | X |
| Horizontal Concrete | X |
| Horizontal Steel | X |
| Horizontal Concrete |    |

Once this has been done, the lookAhead is prepared, as shown in Table N°6. The activities, necessary resources, definition of processes and detection of the restrictions of each activity that cannot yet be executed must be visualized. [9] All those involved in the work must participate in the planning, the objective is to determine the plan for future weeks in order to alert with the request for resources. By making the train of activities, the person in charge of the work will be able to know how much progress will be made each day. [10] know how much progress will be made each day, forecast exactly how much progress will be made on a given day, know how much will be spent per day on the work, have greater control of expenses on the work and advance the work with a minimum of rework. [11]

The delay of one item causes the delay of all items, delaying the system as a whole. [12]

Table

Tabla N°7. Project LookAhead

| Activity Description | QUADRILLA | Week 1 | Week 2 |
|----------------------|-----------|--------|--------|
| L | M | M | J | V | S | L | M | M | J | V |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 0 | 1 | 2 | 3 |

4333
In Table No. 7, once the work sequence has been drawn up, we proceed to elaborate the sequence for activities balancing the loads of the project in question.

| CAL | STEEL | FORMWORK | CONCRETE | STEEL | FORMWORK | CONCRETE | STEEL | FORMWORK | CONCRETE |
|-----|-------|----------|----------|-------|----------|----------|-------|----------|----------|
| L   | 3.00  | 3.00     | 3.00     | 3.00  | 3.00     | 3.00     | 3.00  | 3.00     | 3.00     |
| M   | 0.00  | 0.00     | 0.00     | 0.00  | 0.00     | 0.00     | 0.00  | 0.00     | 0.00     |
|     | 120.  | 120.     | 120.     | 120.  | 120.     | 120.     | 120.  | 120.     | 120.     |
| C   | 0     | 0        | 0        | 0     | 0        | 0        | 0     | 0        | 0        |
|     | 30.0  | 30.0     | 30.0     | 30.0  | 30.0     | 30.0     | 30.0  | 30.0     | 30.0     |

In Table No. 8, the staffing schedule is provided for the project:

| Table No. 8. Staffing Schedule |
|--------------------------------|
| **ITEM** | **L** | **M** | **M** | **J** | **V** | **S** | **L** | **M** | **M** | **J** | **V** | **S** |
|----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| EFFICIENCY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| METRA | | | | | | | | | | | | |
| STEEL | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 0 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| FOUNDATION | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| CONCRETE | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| CONCRETE | 0 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| TOTAL | 3 | 3 | 3 | 3 | 3 | 0 | 5 | 5 | 5 | 5 | 2 | 3 |

| EFFICIENT PERSONNEL | | | | | | | | | | | | |
| STEEL | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| FOUNDATION | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| CONCRETE | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| TOTAL | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 5 | 2 | 3 |
| STAFF | | | | | | | | | | | | |
| STEEL | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| FOUNDATION | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| CONCRETE | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| TOTAL | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 5 | 2 | 2 |

4334
In table N°8, with the elaboration of the look ahead, according to the amount of meter to be performed, we proceed with the personnel schedule to maintain a correct rhythm of work without having to dismiss and then hire by days. [13]

### Table N°9. Restriction analysis

| ITEM | HER IT COM ES FROM | DESCRIPTION OF THE ACTIVITY | DESCRIPTION OF THE RESTRICTION | DATE | RESPONSABLE |
|------|--------------------|-----------------------------|--------------------------------|------|-------------|
| .01  | O/C                | Steel                       | Arrival of 25,000.00 kg of steel at the site | 01  | GP          |
| .01  | O/C                | Contract                    | Arrival of 11 Steel Operators | 01  | ADM         |
| .03  | Contract           |                             | Safety talk to the 11 operators | 01  | PDR         |
| .04  | O/C                | Formwork                    | Arrival of 120 m² of formwork | 02  | JOT         |
| .05  | Contract           |                             | Arrival of 13 carpentry operators | 02  | ADM         |
| .06  | Contract           |                             | Safety talk to the 13 operators | 02  | PDR         |
| .08  | Contract           | Concrete                    | Arrival of 4 concrete workers | 03  | ADM         |
| .09  | Contract           |                             | Safety talk to the 4 concrete workers | 03  | PDR         |
| .10  | O/C                | Concrete                    | Arrival of the 30 m³ of ready-mixed concrete | 04  | JOT         |
| .13  | O/C                | Concrete                    | Arrival of 30 m³ of ready-mixed concrete | 08  | JOT         |
| .02  | HORIZONTAL         |                             |                               |      |             |
| .01  | O/C                | Steel                       | Arrival of 15,000 kg of steel at the site | 08  | JA          |
In Table N° 9, once this is concluded, we proceed with the analysis of restrictions to avoid setbacks during the execution of the work.

### 4. Results

Table N°10. Performance by sector

| Activity                  | Quadril    | HH  |
|---------------------------|------------|-----|
| Vertical Steel            | 56.00      | 0   |
| Vertical Formwork         | 64.00      | 0   |
| Vertical Concrete         | 19.00      | 0   |
| Horizontal Formwork       | 90.00      | 0   |
| Horizontal Steel          | 156.00     | 8.00|
| Horizontal Concrete       | 18.00      | 0   |
| Totals                    | 403.00     | 4.00|

*Efficiency 100%*
Table N°10 and N°11 show that an efficiency of 100% will be obtained by using the calculated crew in accordance with the yields. [14]

Figure 6, after performing the lookAhead, shows the actual personnel curve according to the distribution in time and deadlines in order to meet the needs: manpower, equipment, consumables, critical materials, subcontracting and others. [15]

| Activity        | Quadrella | H | H |
|-----------------|-----------|---|---|
| Vertical Steel  | 11.00     | 00|   |
| Vertical        | 13.00     | 4.00| |
| Formwork        | 3.00      | 00| |
| Concrete        | 18.00     | 4.00| |
| Horizontal Formwork | 31.00 | 8.00| |
| Steel           | 4.00      | 00| |
| Concrete        | 80.00     | 0.00| |
| **Totals**      |           |   | **64**|

**Efficiency** 99%

Figure 6. performance by sector

Tabla N°12. performance by sector

| CONSTRAINT ANALYSIS | WEEK 1 | WEEK 2 |
|---------------------|--------|--------|
| TOTAL NO. OF RESTRICTIONS | 12     | 13     |
| % OF RESTRICTIONS PER WEEK  | 48%   | 52%   |

After analyzing the restrictions, we can see that during the execution of the work, during the first week there will be a total of 48% of the restrictions and for the second week there will be 52%.

5.Conclusions

In order to maintain a correct personnel curve, it is necessary to try to balance the curves so as not to have paralyzed personnel during the execution of the work. It is possible to try to reduce the sectorization in order to minimize the work areas, but it would increase the workloads causing the increase of crews.
The sectorization helps to optimize the production of workers through repetitive work, also helps to have greater control over the items allowing to reduce the time of the process. Perform the Look Ahead in order to create a "shield" 3 to 5 weeks in advance.

This allows us to foresee what is needed so that future activities can be carried out. For the constraint analysis it should be done formally (meeting and minutes of agreements), concrete action should be taken on the identified constraints, in addition to always assign responsible for each constraint, set deadlines and follow u

References
Lung, L., Shaurette, M. (2018), “El trabajo colaborativo, aplicado al diseño y la construcción, para promover la construcción de edificios verdes en Perú”, Rev. ing. constr. Vol.33 No.2, pp.1. Recuperado de: http://dx.doi.org/10.4067/S0718-050732018000200183

Hinostroza, D. Manosalva, O. (2015). aplicación de last planner en edificaciones multifamiliares. Lima, Perú. [Tesis de grado, Universidad Ricardo Palma]. Recuperado de: https://repositorio.urp.edu.pe/bitstream/handle/URP/2224/manosalva_o-

Buleje, K (2012). Productividad en la construcción de un condominio aplicando conceptos de la filosofía lean construcción. Lima, Perú. [Tesis de grado, Universidad Católica del Perú]. Recuperado de: https://repositorio.upc.edu.pe/bitstream/handle/20.500.12404/1691/BULEJE_KENNY_CONDOMINIO_LEAN_CONSTRUCTION.pdf?sequence=1&isAllowed=y

Chokewanca, V. Sotomayor, J. (2018). Sistema last planner para mejorar la planificación en la obra civil del centro de salud picota - san martín. Lima, Perú. [Tesis de grado, Universidad San Martín de Porres]. Recuperado de: http://repositorio.usmp.edu.pe/bitstream/handle/20.500.12727/4235/chokewanka_sotomayor.pdf?sequence=3

Andrade, M., Arrieta, B. (2011), “Last planner system results in subcontract construction company”, Revista de construcción. Vol.10 No.1, pp.36-52. Recuperado de: http://dx.doi.org/10.4067/S0718-915X2011000100005

Cornejo, K. Gonzales, F. Tapia, V. (2017). Implementación de last planner system en actividades de concreto armado para proyectos de edificacion industrial. Lima, Perú. [Tesis de maestria, Universidad Peruana de Ciencias Aplicadas]. Recuperado de: https://repositorioacademico.upc.edu.pe/bitstream/handle/10757/623900/Cornejo_lk.pdf?sequence=13

Angeli, C. (2017). Implementación del sistema last planner en edificación en altura en una empresa constructora: estudio de casos de dos edificios en las comunas de Las Condes y San Miguel. Santiago, Chile. [Tesis de grado, Universidad Andres Bello]. Recuperado de: http://repositorio.unab.cl/xmlui/bitstream/handle/ria/4601/a120179_Angeli_C_Implementacion_del_sistema_last_planner_tesis_2017.pdf?sequence=1&isAllowed=y

Mendoza, W. (2019). implementación del last planner y metodología del valor ganado en proyectos civiles “construccion de puentes”, red vial 5- huacho. Huancayo, Perú. [Tesis de grado, Universidad Nacional del Centro del Perú]. Recuperado de: http://repositorio.ucp.edu.pe/bitstream/handle/UNCP/5555/T010_44573636_T.pdf?sequence=1&isAllowed=y

Jauregui, C. Pairazaman, C. (2016). Aplicación del sistema last planner de la filosofía lean construction para la generacion de valor en la obra conjunto residencial golf los andes - etapa II, lurigancho - choisica 2014. Lima, Perú. [Tesis de grado, Universidad Privada Antenor Orrego]. Recuperado de: http://repositorio.upao.edu.pe/bitstream/handle/11458/2589/CIVIL%20%20Gladis%20Karol%20Tucto%20Pinedo.pdf?sequence=1&isAllowed=y

Hinostroza, D. Manosalva, O. (2015). Aplicación de last planner en edificaciones multifamiliares. Lima, Perú. [Tesis de grado, Universidad Ricardo Palma]. Recuperado de: http://repositorio.urp.edu.pe/bitstream/handle/URP/2224/manosalva_o-

Gonzales, A. (2012). Propuesta de implementación del sistema last planner con el apoyo de modelación 4d para la obra gruesa de edificaciones. Santiago, Chile. [Tesis de grado, Universidad de Chile]. Recuperado

Carranza, R. Tejada, C. (2018). Estudio comparativo de la implementación del last planner system y el sistema tradicional en la construcción de una tienda comercial makro supermayorista, Comas - Lima. Lima, Perú. [Tesis de grado, Universidad San Pedro]. Recuperado de: http://repositorio.usanpedro.edu.pe/bitstream/handle/USANPEDRO/5481/Tesis_58046.pdf?sequence=1&isAllowed=y

Tucto, G. Sanchez, V. (2017). Metodología de aplicación de la filosofía lean construction y last planner system en la región san martín. Lima, Perú. [Tesis de grado, Universidad Nacional de San Martin - Tarapoto]. Recuperado de: http://repositorio.usan.edu.pe/bitstream/handle/11458/2589/CIVIL%20%20Gladis%20Karol%20Tucto%20Pinedo.pdf?sequence=1&isAllowed=y
Herrera, R., Muñoz, F., Avila, B (2020), “Principales requerimientos de una herramienta TI basada en last planner® system”, Rev. ing. constr. Vol.35 No.2, pp.1. Recuperado de: http://dx.doi.org/10.4067/S0718-50732020000200126

Díaz, L., De Olivera, M., Pucharelli, P., Pinzón, J. (2019), “Integración entre el sistema last planner y el sistema de gestión de calidad aplicados en el sector de la construcción civil”, Rev. ing. constr. Vol.34 No.2, pp.1. Recuperado de: http://dx.doi.org/10.4067/S0718-50732019000200146