FORMULATING THE WORK FLOW PLAN FOR HORIZONTAL PROJECTS – CASE STUDY

Fernanda Aranha Saffaro[1] and Edi Carlos Pires de Paula[2]

ABSTRACT

Recently much research has been done in the field of Production Management, focusing on the concepts and principles of Lean Construction. Regarding the topic Production Planning, some contributions are extremely important as they aim to protect production from uncertainty and also to fight variability through a new insight into the productive process. However, in the first stage of preparation of the planning process, where the formulation of the work flow plan (object of this study) takes place, there is still insufficient research, in spite of the importance of this issue for the definition of the physical flows in the building site.

Regarding this issue, a case study was developed in a small construction company, aiming to clarify what the scope of a program which formulates the work flow plan would be, and also to explain how this stage of the planning process can be appended to the Production Planning and Control Model proposed by NORIE (Post-Graduation Program on Civil Engineering - Federal University of Rio Grande do Sul).

KEY WORDS

Lean construction, work flow, physical flows, production planning and control, strategic plan.

[1] Assistant Professor, Construction Department, University Campus – Rodovia Celso Gracia Cid (PR 445), Km 380, State University of Londrina, Londrina-PR, CEP 86051-990, Brazil, 43 371-4455, FAX 43 371-4082, saffaro@uel.br

[2] Under graduate student, University campus – Rodovia Celso Gracia Cid (PR 445), Km 380, State University of Londrina, Londrina-PR, CEP 86051-990, Brazil, 43 371-4455, FAX 43 371-4082, edicarlos@uel.br

INTRODUCTION

Current research on Production Management based on the concepts and principles of Lean Construction have brought important contributions to specific themes, such as Production Planning.

One of the problems usually faced by construction companies in their production planning and control processes is the fact that uncertainty is neglected, and excessively detailed plans are produced for relatively long time horizons. In this manner, too much work is spent updating plans and their effectiveness is affected. Besides, the emphasis on the production of plans and also on the techniques used for generating them tends to compromise the understanding of planning and control as a managerial process.

Ballard (1997) suggested three planning levels. The first level is the master plan, also called 'long term', with a low detail level, a large time horizon and low adjustment frequency. The second level is the lookahead planning that makes the link between the long and the short term, determining what *can* be done and so shielding production. Finally, the third is the commitment planning (short term), where commitments are made to do what *should* be done, only to the extent that it *can* be done.

Laufer and Tucker (1987) presented the planning process as shown in Figure 1, demonstrating its dynamic character, which is characteristic of a process.

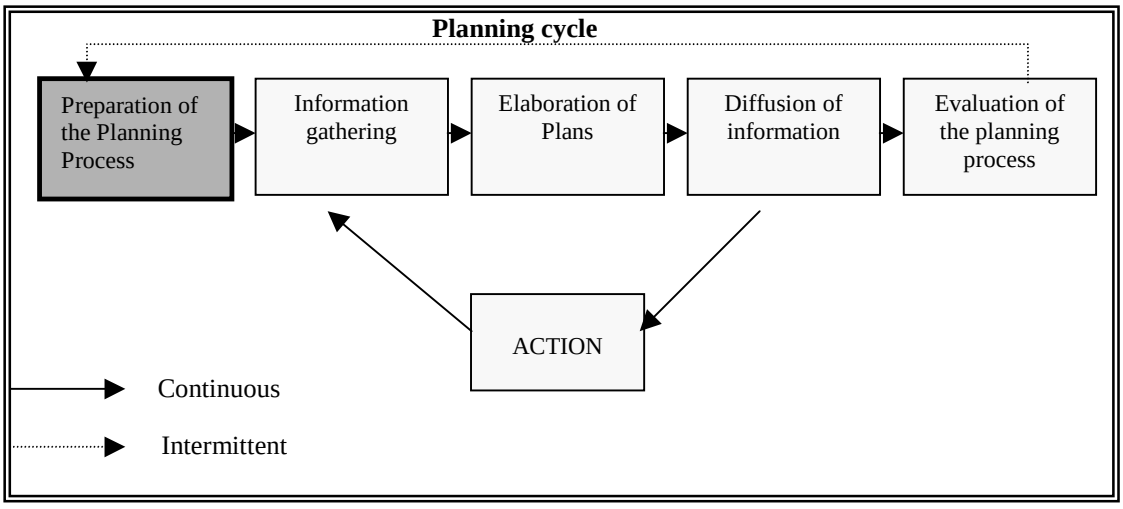

Figure 1: The Planning Process (Laufer and Tucker 1987)

Therefore, there are two important contributions regarding planning. One of them is the search to reduce uncertainty by elaborating plans with different horizons and detail levels. The other one is the understanding of the planning as a process.

Bernardes (2001) developed a planning model (Figure 2), which takes into account both the three planning levels proposed by Ballard (1997), called vertical dimension, and the stages of the planning process, depicted in Figure 1, which characterizes the horizontal dimension.

The Preparation of the Planning Process is the first step of the planning process, in which decisions are taken regarding the detail level and the frequency of re-planning, as well as the scheduling technique (Bernardes 2001).

Another important task developed at this first step is the definition of Work Breakdown Structure (WBS), which must be developed simultaneously to the analysis of the work zone. In spite of the importance of the WBS definition for the consistency between long, medium and short term plans, the conversion view still persists in the segmentation of the activities making flows less explicit and harming the application of Lean Construction principles (Bernardes 2001; Alves 2000).

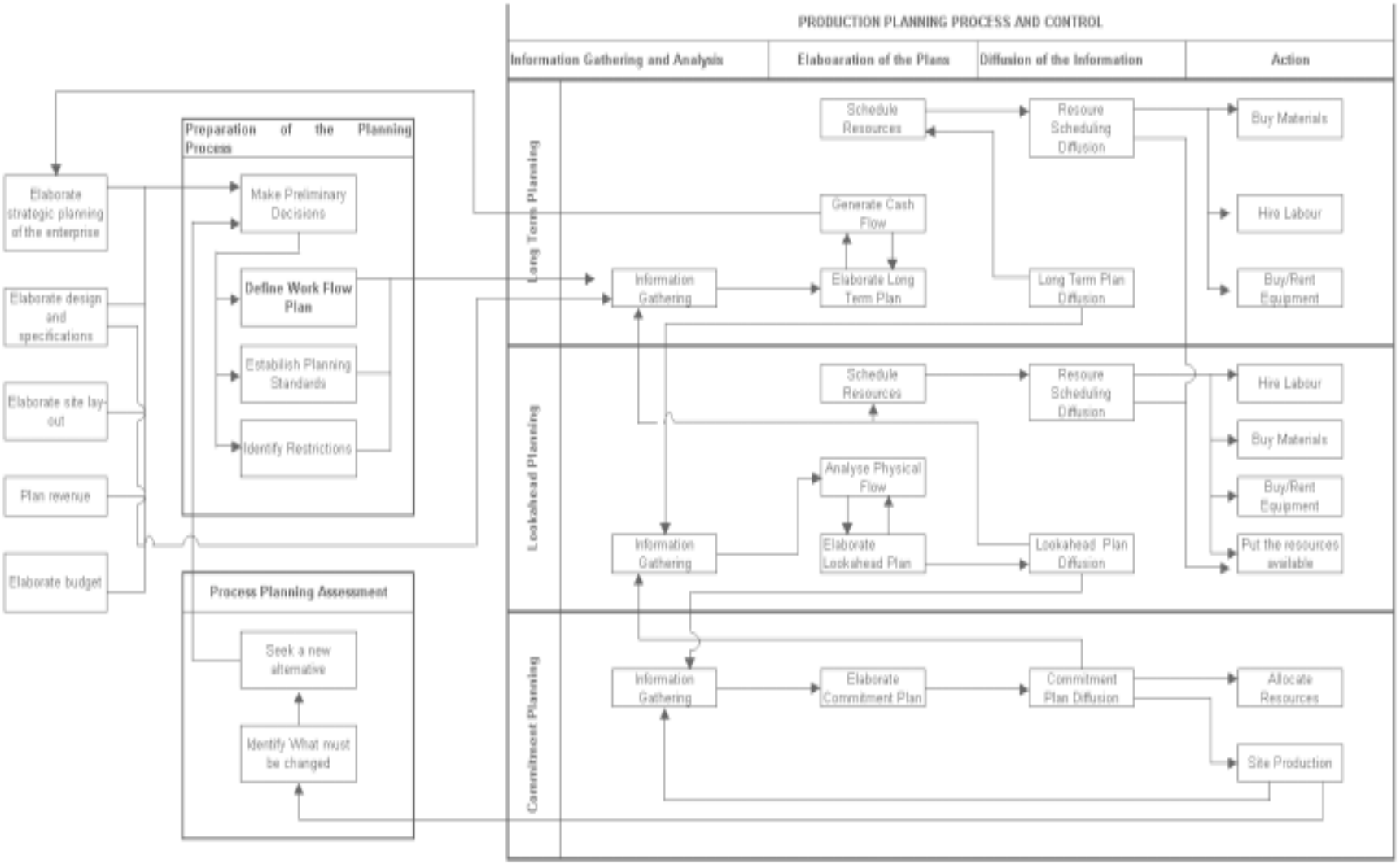

Figure 2: Production Planning and Control Model proposed by NORIE (Bernardes 2001)

Figure 3 shows the tasks involved in the Preparation of the Planning Process and their interfaces with the first level of the vertical dimension (long term planning).

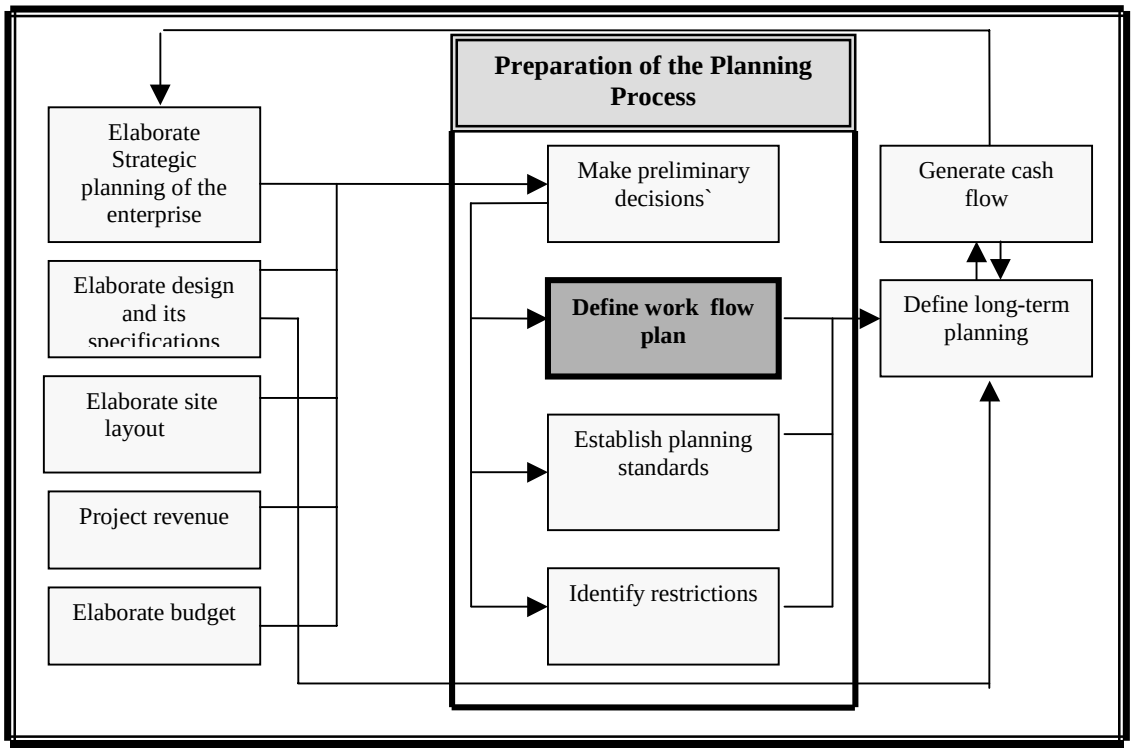

Figure 3: Preparation of the Planning Process (Bernardes 2001)

It is important to stress that although the Preparation of the Planning Process includes other tasks, this study is focused on the definition of the strategic plan, where there is a lack of broader studies. The research is concerned, more specifically, with the development of a work flow plan (WFP) in order to identify its scope, since the literature does not clearly state its boundaries . The researchers also worked with the proposition that the WFP could enhance long term and lookahead efficiency. However, there was no data elucidating the contents of a WFP, nor any research describing the implications of a WFP in the following stages of the planning process and production control.

METHOD

According to the lack of knowledge and the proposition highlighted, there were basically three research questions to be answered in this case study:

- What should be the scope of a WFP?
- Which are the WFP time limits in the Planning Process and Production Control?
- What are the implications of the elaboration of a WFP in vertical and horizontal dimensions in the model studied?

In order to answer these research questions, a case study was developed as part of a research project called GEHIS[3], involving four academic institutions in 4 Brazilian states, coordinated by NORIE (Post-Graduation Program on Civil Engineering - Federal University of Rio Grande do Sul) . It was applied to a small construction firm located in the city of Londrina- PR.

The project analysed in the case study was a low income housing enterprise financed by a Federal bank and it has 10 blocks of 2 floors, with 4 apartments per floor.

The location of the 10 blocks on the land created a good opportunity for the researchers and management team[4] to issues regarding the physical flow in the site, which, according to premises of the researchers, was an important topic of the WFP.

What interested the company in this study was the fact that other enterprises would be executed with the same characteristics as this one, in other words, with the same line of credit for financing and similarities in the layout of the blocks distribution on the land.

The researchers set up a work plan to answer the research questions and its steps are listed below:

1. Elaboration of an initial script for the formulation of WFP based on the experience of the researchers;
2. Presentation of the initial script for evaluation and complementation by the management team;
3. Application of the script to formulate the WFP of the project;
4. Elaboration of the long-term planning, keeping record of the contributions to the complementation of the initial script and its implications in this vertical dimension;
5. Elaboration of the site lay-out design;
6. Elaboration of the lookahead planning, keeping record of the contributions to the complementation of the initial script and its implications in this vertical dimension. This step includes the physical flows statement;
7. Implementation of the short-term planning (last planner), keeping record of the contributions to the complementation of the initial script and its implications in this vertical dimension;
8. Presentation of the final version of the Script for Formulating Work Flow Plan.
9. Presentation of a DFD, clarifying the information flow from the WFP to the long term and lookahead planning.

RESULTS

Construction work has not started yet and at the moment the project is in its final stage of revising the long-term planning (item number 4 in the work plan).

Due to the time limitations of the research project, the results presented here do not include a final version of the Script for Formulating Work Flow Plan, nor the implications of its application in the vertical dimensions. However, there are interesting results concerning the interface of WFP and the long term planning.

---

[3] research project named “Low income housing management: an integrated model for product development and production management aimed at cost reduction - GEHIS”.

[4] The engineer who owns the firm and two other engineers made up the management team. Only one of them will be the responsible technician of the enterprise.

PROPOSED SCRIPT

Table 1 presents an initial proposal of the Script for Formulating Work Flow Plan.

Table 1: Script for Formulating Work Flow Plan (initial proposal)

SCOPE OF THE DECISION	VARIATIONS OF THE SCOPE	CRITÉRIA FOR DECISION MAKING	DECISION TAKEN
Accessibility and ground conditions	Pathways	▪ Identification and selection of pathways ▪ Pathways condition (tarmac and traffic) ▪ Vehicles to deliver material	▪ Main pathway (tarmac) ▪ Precautions when driving (heavy trucks)
	Intensity of traffic	▪ Time schedule for material delivery	▪ Unnecessary
	Pre-existing Facilities	▪ Demolition ▪ Used for site installation	▪ Non-existing
	Retaining Wall	▪ Uneven ground ▪ Digging ▪ Landfill	▪ Unnecessary
Production Strategy	Delivery of the units (apartments, houses,...)	▪ Sequence of execution and units delivery ▪ Isolation of delivered areas ▪ Delivery deadlines ▪ Physical flows ▪ Lead time compression	▪ Simultaneous delivery of all units
	Sequences	▪ Construction technology ▪ Delivery sequence of units ▪ Cash flow ▪ Easy storage and material flows	Infra-structure→ foundations →brickwork / structure → finishings → leisure area
	Path	▪ Structure (↑) → brickwork (↑)→external plastering (↓) → painting (↑); ▪ Structure (↑)→brickwork(↑)→ external plastering (↑) → painting (↑);	Structure / brickwork (↑)→ internal plastering → external plastering.(↓) → internal painting (↑) → external painting (↓)
Technology	Structural system	▪ Concrete supply (premix or mixed at the site) ▪ Steel supply (pre cut or done at the site) ▪ Formwork (BKS, Gethal, conventional) and fabricated on site or off site. ▪ Support system (wood or metal; bought or rented))	▪ Columns – concrete mixed at the site ▪ Slabs–premix concrete ▪ Precut steel –price research ▪ Formwork – wood or metal (?) ▪ Support System - wood
	Installation	▪ Use of kits ▪ Use of systems (pex, PVC, cooper pipes,...)	▪ Use of hydraulic kits ▪ Use of PVC
	Insulation	▪ Type of block ▪ Modularization analysis (walls) ▪ Type of mortar	▪ Brick 9x20x20 ▪ Try modularization ▪ Industrialized mortar/ manufactured on site (?)

SCOPE OF THE DECISION	VARIATIONS OF THE SCOPE	CRITÉRIA FOR DECISION MAKING	DECISION TAKEN
Technology	Plastering	▪ Gypsum or plastering ▪ Type of mortar	▪ Plastering ▪ The same as brickwork
	Openings	▪ Pre-set door kit or door frames/door	▪ Pre-set door kit
Machinery and equipment	Vertical and horizontal transportation	▪ Analysis and selection of alternatives (crane, site elevator, mortar and concrete carts, pallet cart , bob-cat) ▪ Buying / renting / using own	▪ Rented site elevator ▪ Maybe rented bob-cat ▪ Own carts
	Processing	▪ Demand analysis (production capacity x installed capacity) ▪ Analysis and selection of alternatives ▪ Buying / renting / using own	▪ Mortar mixer – Buying / renting / using own (?)
Materials	Suppliers	▪ Type of delivery (pallet) ▪ Partnerships	▪ Non pallet delivery ▪ Delivery done in parts
	Reception	▪ Standard procedures	▪ Some materials (Quality Program)
Labor work	Hiring	▪ Which services will be done by hired labor work	▪ Services usually hired by the company

Because those were initial contributions to the definition of the scope of WFP, there was some concern regarding the format of this script. The adaptations suffered throughout time can be incorporated to the initial proposal with no damage to the logical formulation of a WFP.

According to the format proposed in this script, the WFP results in decisions that will guide the execution and management strategies of the project. Therefore, there must be some concern with the way the decisions are taken. For this reason, the proposed format includes the following topics: scope of the decision, variations of the scope, criteria for decision-making and eventually, the decision taken. During the formulation of the WFP in this case study, the researchers registered the reason for the decisions taken, including one more column, which is not presented here due to the limited number of pages allowed.

WORK FLOW PLAN X LONG-TERM PLANNING

The line of balance (LOB) was used as a technique for the elaboration of the long-term plan. The reason for choosing this technique was the repetitive characteristic of the project and also its graphic capacity to make clear the decisions taken during the formulation of the WFP. Besides, the expectation of the researchers was that while building the line of balance there would be complementation in the WFP proposed script or that the decisions already made would be thought over.

Some decisions were not taken in the application of this script due to the unavailability of information mentioned in the topic “Criteria for Decision Making”. They are:

- Formwork to be used – wood or metal;

- Type of mortar to be used – industrialized mortar or manufactured on site;
- Mortar mixer - Buying / renting / using its own

In the first two cases the decision depends on a comparative cost analysis between the two options. The decision to buy, rent or use the mortar mixers available in the company depended on a demand analysis compared to the already installed capacity (Santos 1995).

During the long-term planning elaboration (item number 4 in the work plan previously listed) a decision between the two options of the formwork was necessary, since there were implications in the definition of the work package[5], in the duration, and consequently in the working rhythm of the "Structure-Brickwork" crew.

Only after the elaboration of the long-term planning, when the number of crews and the work flow[6] for the "Brickwork/Structure", "Internal Plastering" and "External Plastering" activities were defined it was possible to identify the demand of the mortar mixers.

The expectation of the researchers regarding the retake of discussions about the WFP was confirmed when the line of balance was elaborated. At this stage issues such as the sequence and the path of the execution of the "Brickwork/Structure" activity were reexamined. The issue then raised was regarding the possibility of the same crew to carry out this activity on both floors , which, only after finishing each block, should move on to the next one (Alternative A – Figure 4). On the other hand, there was an initial proposal from the management team, suggesting that the crew should move around, executing the "Brickwork/Structure" activity only on the first floors of all blocks and only then should they go back and perform the same activity on the second floor of all blocks (Alternative B – Figure 4).

[5] work package: a group of similar tasks performed in a specific area based on the work zone analysis. This work package makes use of specific information of the design, labor work, material and equipment and it should have its prerequisites ready in time to be executed (Choo et al, 1999). Therefore, in order to establish work packages it is necessary to elaborate a Work Breakdown Structure (WBS) to define the tasks which will be part of the package and also proceed with work zone analysis so that the crew can accomplish the tasks of a specific area within reasonable time for planning.

[6] Alves (2000) generically defines physical flows as material and labor work flow, whereas Formoso et al. (1999) use the term work flow to designate a group of operations accomplished by a certain production crew.

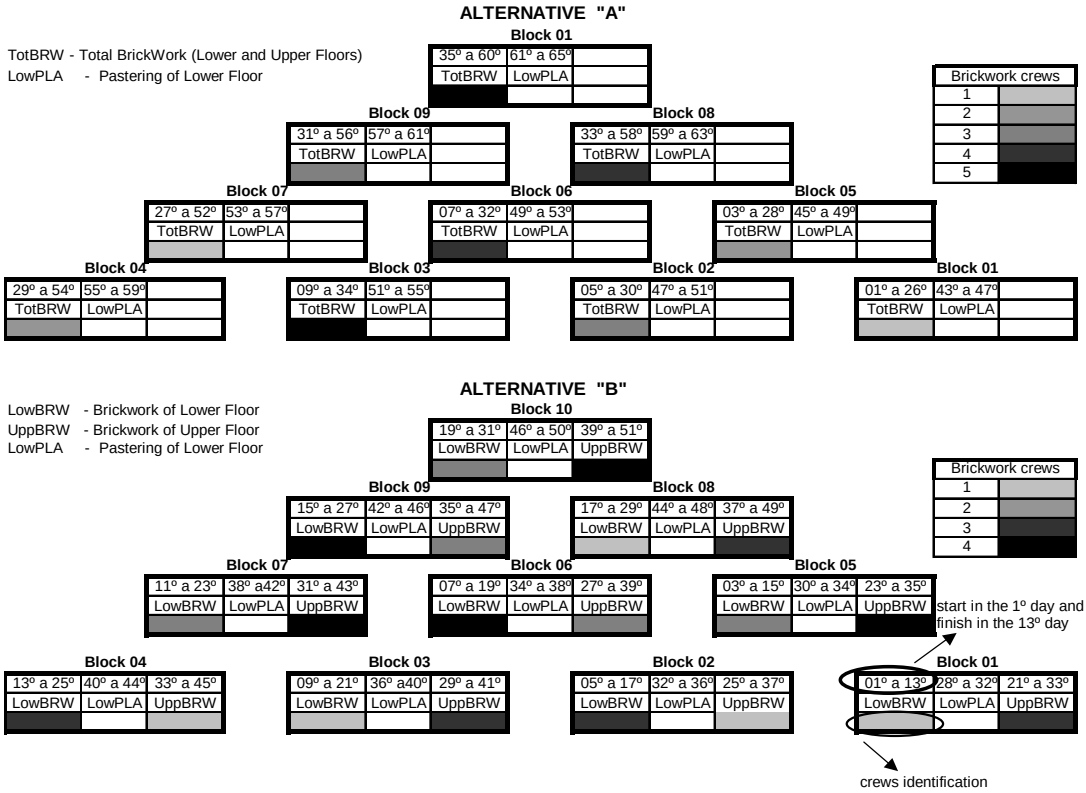

Figure 4: Work Flows of the Brickwork and Internal Plastering activities

This discussion had effects on the physical flow of the site and it demanded the representation of the work flow in the implantation project. This happens because of the deficiency of the line of balance when it represents the material and equipment flow (Tommelein 1998).

Figure 4 shows the work flow obtained from the line of balance, which allowed the positioning of the mortar and concrete production area, defining the amount of necessary mortar mixers, its movement in the site and still, the storage areas and the material flow. These physical flows will be considered in the elaboration of the site layout design (item number 5 in the work plan previously listed).

Another item of the WFP, which was reexamined at this point and favored by the work flow demarcation (Figure 4), was the possibility of delivery of a group of blocks done in parts. This strategy would bring benefits to the physical flow, reducing transportation distances, and also to the compression of the lead time[7], which would guarantee faster delivery of the units and would still allow for adjustments in the production process and the incorporation of eventual requirements from clients when producing the following blocks (Shingo 1996).

It is important to highlight that the demarcation of the work flow (Figure 4) contributed for transparency in space and time distribution of the crews and the material, which made the analysis of the physical flows, the evaluation of interference between the crews, the location of the production area and material storage a lot easier. Usually the

[7] Koskela (2000) refers to lead time as the time required for a particular piece of material to transverse the flow. The lead time can be represented as Lead Time = processing time + inspection time + wait time + move time.

broaching of these factors is despised by the managers, even tough its importance has been highlighted by some authors Alves 2000; Santos 1995; Birrel 1980).

The discussion presented here shows that even after the WFP had been formalized, there were a lot of decisions retaken and intense exchange of information between this stage and the long term planning. As construction work has not started yet, this case study was interrupted and another one should be applied to check information flow to the lookahead and to complete the script presented here. Figure 5 presents the proposal design of the Preparation of the Planning Process.

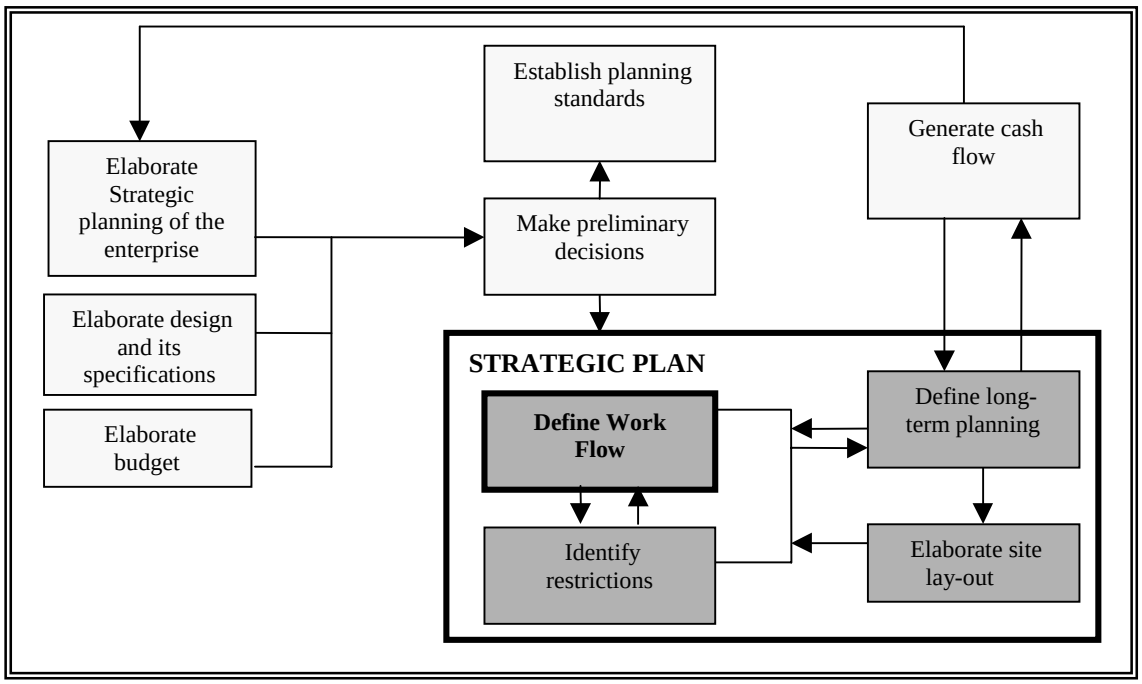

Figure 5: Preparation of the Planning Process (Proposal)

FINAL COMMENTS

The studies developed so far indicate that there is not a clear time demarcation between the formulation of the WFP and the elaboration of the long-term planning. In this case study there was an overlapping of both activities, since during the formulation of the long-term planning, some information that was still vague during the formulation of the WFP was clarified, leading back to previous discussions.

The elaboration of the site layout in stages prior to the formulation of the WFP as the production planning and control model proposed by Bernardes (2001) suggests is also questioned. This study shows that the maturity of the questions related to physical flow occurs later than the formulation of WFP, simultaneously to the long term planning, and then they are incorporated to the site layout design. According to Alves (2000), the study of the site layout should be based on long-term planning, when it is possible to identify time and space conflicts.

Although the line of balance has not been properly applied for controlling production in this case study, it seems clear that this planning technique facilitates discussions on flow management at this stage of the planning process. This kind of discussion is usually made at the lookahead planning level, when there is little time for implementing changes

in physical flows. These questionings lead us to believe that the WFP has a bigger time and functional role than what is proposed in the PCP model studied, indicating the need to revise the Preparation of the Planning Process stage presented there, aiming at better clarifying the planning process flow, specially in horizontal projects, where physical flows are valued.

REFERENCES

Alves, T. (2000). Diretrizes para a Gestão dos Fluxos Físicos em Canteiros de Obras: Proposta Baseada em Estudo de Caso (Guidelines for physical flow management at the building site: proposal based on a case study) . Dissertação de Mestrado, Programa de Pós Graduação em Engenharia Civil, Universidade Federal do Rio Grande do Sul., Porto Alegre, RS, 139 pp.

Ballard, G. (1997). Lookahead planning: the missing link in production control, Proc. 5th Ann. Conf. Intl. Group for Lean Constr., IGLC-5, pp 13-25, Gold Coast, Queensland, Australia.

Bernardes, M.M.S. (2001). Desenvolvimento de um Modelo de Planejamento e Controle da Produção para Micro e Pequenas Empresas de Construção. (Development of a Planning Model and Production Control for small construction firms). Tese de Doutorado, Programa de Pós Graduação em Engenharia Civil, Universidade Federal do Rio Grande do Sul., Porto Alegre, RS, 285 pp.

Birrell, G. (1980). "Construction planning beyond the critical path". Journal of the Construction Division, ASCE, New York, NY, 106 (3) 389-407.

Choo, H., Tommelein, I.D. and Ballard, G. (1999). "WorkPlan: Constraint-Based Database for Work Package Scheduling". J. Constr. Engrg. and Mgmt., ASCE, New York, NY, 125 (3) 151-160.

Formoso, C.T., Bernardes, M.M.S. , Oliveira, L., Oliveira K. (1999)"Termo de Referência para o Planejamento e Controle da Produção em Empresas Construtoras". (Reference term for Planning and Production Control in building firms). Programa de Pós Graduação em Engenharia Civil, Universidade Federal do Rio Grande do Sul., Porto Alegre, RS.

Koskela, L. (2000). An Exploration Towards a Production Theory and its Application to Construction. PhD Dissertation, VTT Building Technology, Espoo, Finland. VTT Publications: 408, ISBN 951-38-5565-1; 951-38-5566-X, 296 pp.

Laufer, A; Tucker, R.L. (1987) Is construction planing really doing its job ? A critical examination of focus, role and process. Construction Management and Economics, London, (5) 243-266.

Santos, A. (1995). Método de Intervenção em Obras de Edificação enfocando o Sistema de Movimentação e Armazenamento de Materiais: Um Estudo de Caso. (Intervention Method in Construction focusing on the Transport and Storage System, a Case Study). Dissertação de Mestrado, Programa de Pós Graduação em Engenharia Civil, Universidade Federal do Rio Grande do Sul., Porto Alegre, RS, 150 pp.

Shingo, S. (1996). O Sistema Toyota de Produção: do ponto de vista da engenharia de produção. (A study of the Toyota Production System from an Industrial Engineering Viewpoint), Artes Médicas, Porto Alegre, RS.

Tommelein, I.D. (1998). "Pull-Driven Scheduling for Pipe-Spool Installation: Simulation of Lean Construction Technique". J. Constr. Engrg. and Mgmt., ASCE, New York, NY, 124 (4) 279-288.