MODELING INFORMATION FLOWS BETWEEN LAST PLANNER AND LOCATION BASED MANAGEMENT SYSTEM

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- **ABSTRACT**

Production planning and control are two of the most important aspects that contribute towards the successful completion of construction projects. The Last Planner® System (LPS) and Location Based Management System (LBMS) have emerged as two popular methods for production planning and control. Previous research has shown that by combining LPS and LBMS there is an opportunity to improve production tracking, forecasting and control and described the process of how the systems can be combined.

However the research has stopped short of developing specific information flows between the two systems. In particular, the use of LBMS forecasts in LPS lookahead planning and the use of LPS constraints in LBMS forecasting lack specific guidelines. Information can be moved in several different ways and research is needed to make sure that the integration adds value. The goal of this research is to evaluate alternative ways to integrate the information in LBMS and LPS systems. Thought experiments and simple scenarios were used to evaluate the benefits and drawbacks of different approaches. The result is an initial proof of concept that can be implemented manually or automated in LBMS and LPS software applications.

- **KEYWORDS**

Production Control, Last Planner System, Location Based Scheduling, Production Planning.

- **INTRODUCTION**

The Last Planner System (LPS) supports site based production processes, replacing ad-hoc and "push" based traditional systems (Ballard 2000). The Location Based Management System (LBMS) provides a much needed spatial element to planning and has strong optimisation and forecasting capability that can help plan and steer the project towards its goals (Kenley and Seppänen 2010). Studies over the years have highlighted that there is a risk of losing sight of the big picture if LPS is not sufficiently integrated with high level planning and tracking (Dave et al., 2015), whereas the LBMS

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system lacks the constraint screening and weekly planning processes. From this perspective, both these systems have complementary features which if combined properly – can improve the production management on site significantly (Seppänen, Modrich, and Ballard 2015; Dave et al., 2015).

While previous studies have explored synergic potential of LPS and LBMS (Seppänen, Modrich, and Ballard 2015; Seppänen, Ballard, and Pesonen 2010; Dave et al., 2015), they have yet to clearly define the workflows and integration of functions from both these systems. For example, how will forecast information be brought to help the lookahead planning function in LPS, and whether the updated plan with constraints should be taken into consideration in LBMS, or how will the updated execution statuses from LPS will be brought into LBMS each week, are some examples of questions that need addressing for field implementation of these two systems.

From the perspective of integration, Master and Phase scheduling are reasonably clear from workflow perspective. As has been proposed in previous studies, Master and Phase scheduling will be carried out in LBMS based on LPS social process. These plans provide a starting point for more detailed lookahead and weekly planning of LPS. The workflow for information exchange at Master and Phase schedule level is defined well in previous research (Seppänen, Ballard, and Pesonen 2010; Seppänen, Modrich, and Ballard 2015).

- **FUNCTIONAL INTEGRATION**

Lookahead planning involves bringing all stakeholders together, creating sub-tasks from the milestone schedule, identifying and assigning responsibility to constraints and commitment from workers in removing these constraints (Ballard 2000). While LPS tackles the collaborative planning and constraints analysis effectively, LBMS has the capability to provide a much needed "big picture" through the live forecasts. When planning their detailed execution plans, the crew should have access to time-location boxes in LBMS schedule. In LBMS the flow of work is clearly defined within locations, hence the workers can identify how much time each of them have at each location and when do they have to handover to the next trade.

On the other hand, the LBMS schedule generally does not tackle detailed task level planning or identification of constraints which could have an impact on forecasts. Figure 11 outlines the proposed workflow for a combined LPS and LBMS implementation for lookahead planning. In the weekly planning, one of the main features of LPS is commitment from the team and screening for unfit tasks and removing them from the execution schedule.

One of the biggest risks from production perspective at this stage is to lose sight of the big picture, i.e. there is not reverse feedback to inform the team of the impact the changes will have on the schedule if they remove unfit activities. This gap can be filled by i) feeding the actual task statuses from LPS to LBMS; ii) feeding the updated/live weekly plan data to LBMS and checking the forecasts. Another important aspect is that the crew will have access to the time-location boxes, i.e. each team will know when the location becomes available for them and the deadline by which they have to deliver the location to the next team. As shown in Figure 14, a time-location box is a visual notation in LBMS that shows the available time window for a particular location handover to the crew. In other words, all work related to that activity and location should be completed within the time-location box. If the weekly plan changes impact this, the LBMS schedule can raise an alarm to inform the team of potential clashes. Subsequent

sections in the paper will provide in-depth explanation of the workflow and integration between the functions.
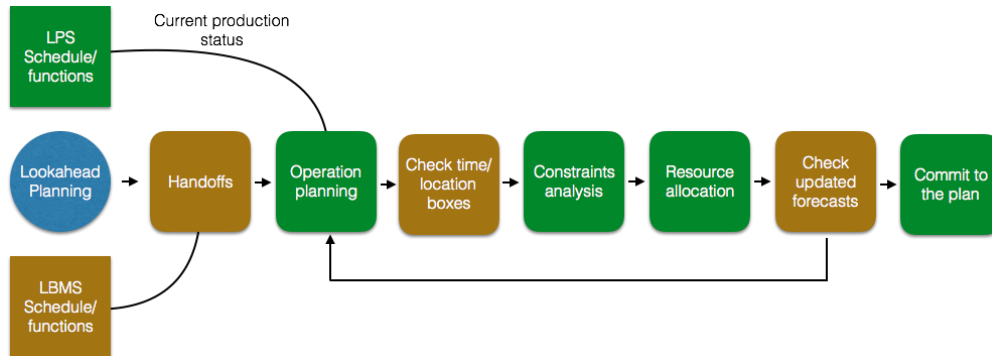

Figure 11 - LPS-LBMS Combined Lookahead workflow

• METHODOLOGY

The research is based on constructive research strategy, which aims to tackle a practical problem and devise experiments, which are then iterated and validated through user feedback. The typical steps in constructive research approach (Lukka 2003; von Alan et al., 2004) are, i) identification of a practically relevant problem; ii) examining the potential for research; iii) obtaining deep understanding of problem area, theoretically and practically; iv) innovate a solution idea; v) implementing the solution; vi) ponder the scope of applicability of the solution; vii) identifying and analysing the theoretical contributions. The current research stage is "innovate a solution idea". The subsequent stages of implementation to theoretical contributions will be developed in subsequent research.

• RESULTS

The following are recommendations to integrate LPS and LBMS at various planning and execution stages. The workflow is explained through a simple schedule of 2 tasks which are carried out in 5 locations, Figure 12 shows the LBMS schedule.

• MASTER SCHEDULING

Master Scheduling in LPS is considered to be equivalent to identifying major milestones for the project. Due to its strong optimisation capabilities, it is recommended that the Master plan would be developed in LBMS, where major milestones will be identified.

• PHASE SCHEDULING

Seppänen, Modrich, and Ballard (2015) suggested starting reverse phase scheduling using the LPS social process of carrying out a collaborative workshop where the site team works backwards from the master schedule milestone. In contrast with the LPS – only workshop, durations would not be discussed in this workshop. Rather, a "homework assignment" would be given to participants to detail their quantities and labour consumption data by location for each task. These quantities and labour consumptions would be used to create the first version of the schedule based on preferred crew sizes and then the schedule would be optimized collaboratively using LBMS in another optimization workshop.
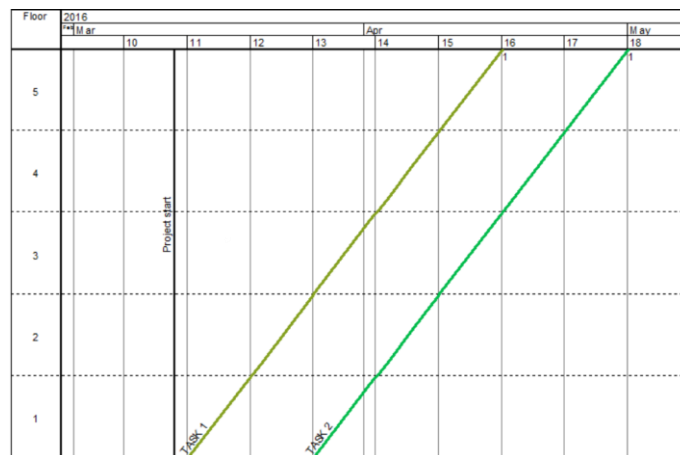
Figure 12 - Master Schedule in LBMS with 2 activities and 5 locations

After Phase Scheduling has been completed, the Phase schedule data from LBMS would be imported in LPS system. The information can then be shown in a simple Gantt view and subsequently in the timeline view (Figure 18) once the resources (workers) are allocated to tasks. Figure 13 shows the imported Phase schedule from LBMS system, with activity-location handover date shown as a milestone (red diamond). Each time-location box from the LBMS schedule (as shown in Figure 14) will also be available to the LPS crew when carrying out lookahead and weekly planning activities.

Figure 13 - LBMS Schedule imported as Master plan for LPS

- **LOOKAHEAD PLANNING**

The crew members will perform the lookahead planning using the Phase Scheduling data from LBMS. First, the tasks will be divided into operations which can then be assigned to workers. In this case (as shown in Figure 15), each activity-location is subdivided into two operations, which are to be carried out by two crews (each crew with two workers). The "exploded" schedule is shown in Figure 15.

Once the operations are created, they will be assigned to individual workers or foreman as shown in Figure 18. After the initial task allocation, the lookahead team identify task constraints and realise that activity 1 has a space constraint on location 3 which has to be rescheduled from its original date. Example of an app interface for the

workers is shown in Figures 6 and 7 (where the workers will update the constraints on each selected activity).
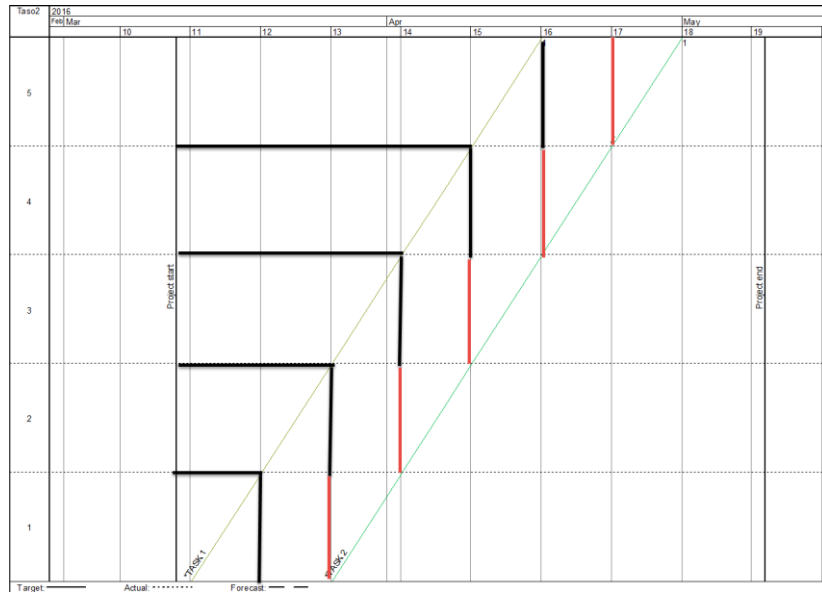

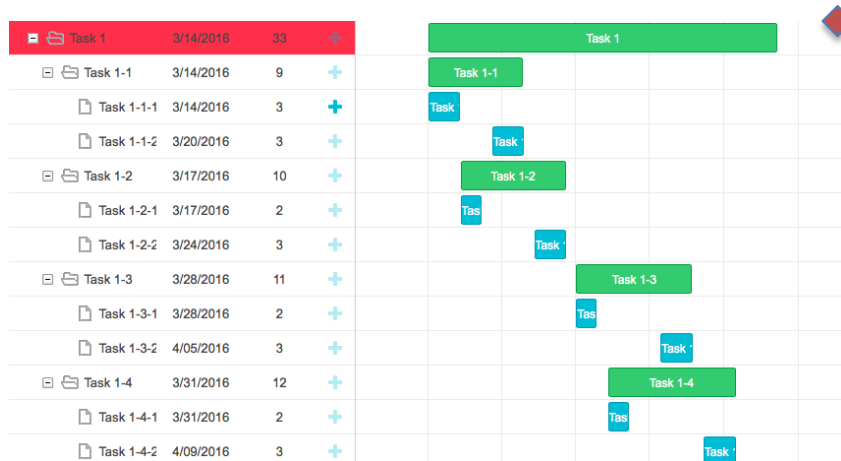Figure 14 - Time location boxes in LBMS schedule

Figure 15 - Task 1 Exploded in LPS to create Lookahead schedule

The weekly subcontractor meeting has two purposes, first lookahead planning for the next 6 weeks ahead on a task level of detail. The lookahead planning is then followed by the weekly work planning for the next two weeks ahead on an operations /steps level of detail. From this perspective, during the lookahead planning meeting, the crew will have access to the forecasts from LBMS schedule, and each time/location handover date is shown as a sub-milestone for activities as shown in Figure 12. If changes to the plan impact these location milestones, an alarm would be raised in the LPS system to notify the crew. After negotiation, the crew will commit to the schedule and subsequently the LBMS forecast will be updated with this information. The lookahead and weekly planning schedules in LPS will have preserved the links to the higher level plans (phase and master) by following a Task ID -> Sub Id structure. This way the real-time feedback on task statuses will update the phase and master plan level tasks and

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inform the crew of potential delays or other problems during the weekly and lookahead planning sessions. Each crew/location will have their own display board showing the current weekly plan which can be used during the daily stand-up meetings where the real-time progress from the LPS plans can be discussed.
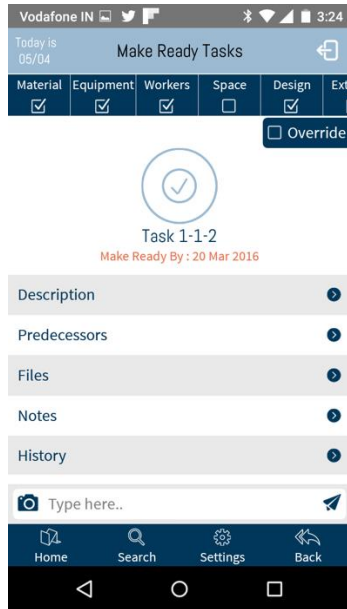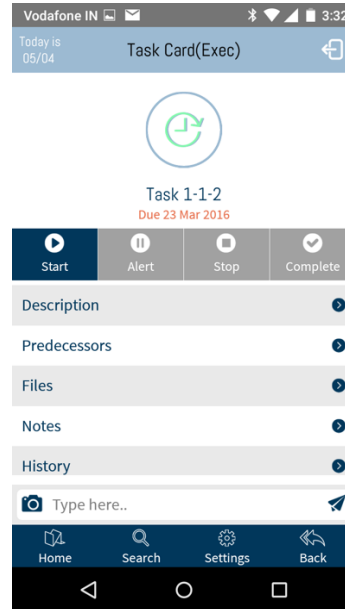

Figure 16 - Updating task constraints in LPS

Figure 17 - Task execution data from LPS

In the example discussed here, the impact from the initial re-planning of the layout tasks in LPS following the identification of the space constraint would have delayed the framing activity, and overall the activity would have been delayed by a week. However, in the new workflow the crew has access to the LBMS schedule, and they reorganise the activities in such a way that layout on floors 1-2 will be handed over 1 week earlier and framing will be brought forward one week so that following the delay by space constraint, the layout crew on floors 3-5 will be able to handover the location to framing (floors 3-5) on time. This way the overall handover of Task 1 can be carried out as planned.
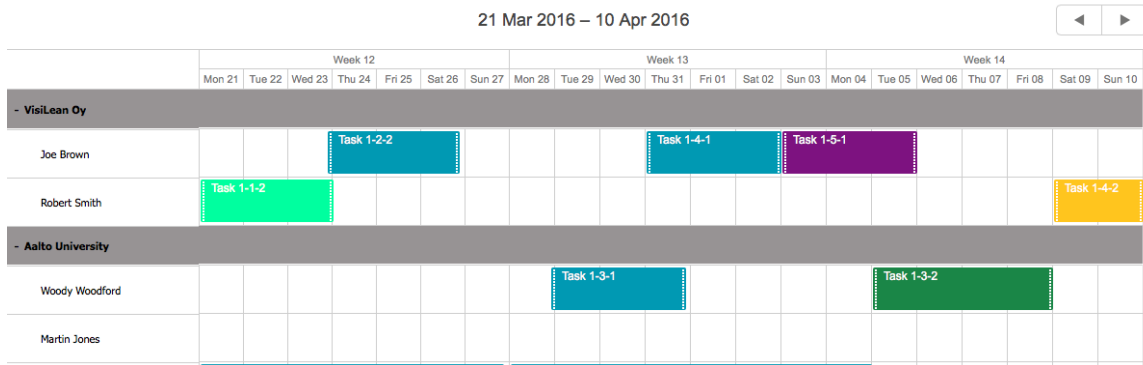
Figure 18 - Tasks allocation for the lookahead planning

Figure 19 shows the updated LBMS schedule following the Lookahead planning session, where the x-axis shows the duration in weeks and the y-axis shows the location (floors 1-5). It can be seen from the rearranged tasks that although the overall hand-off date is on time, individual locations are performed late (outside their "box") which will delay the succeeding subcontractor. This will trigger negotiation and re-planning to mitigate the impact.
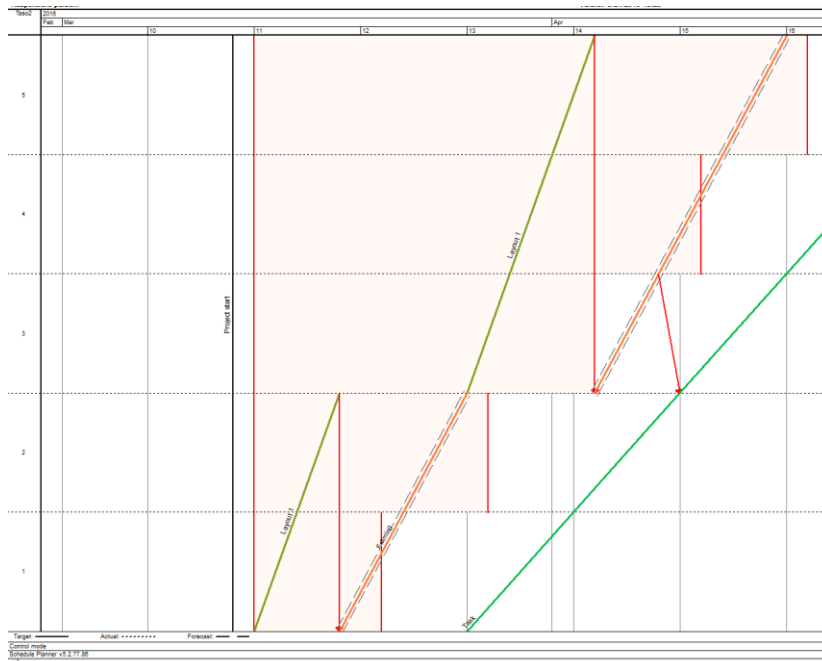

Figure 19 – Updated LBMS schedule after Lookahead session

Following the Lookahead meeting and the weekly planning session, the crew updates the commitment plan with latest task updates (execution) from the field. Figure 17 shows the interface for crew when updating the activities from the field. If a planned activity, including constraining (or predecessor) activity fails to complete on time, the system will raise and alarm and the LBMS schedule will be updated accordingly. The combined system would raise an alarm if the low productivity or a constraining task results in delay. Similarly, the actual start and finish dates from the LPS system will be used to update the LBMS to ensure the forecasts remain up-to-date and alarms raised if needed.
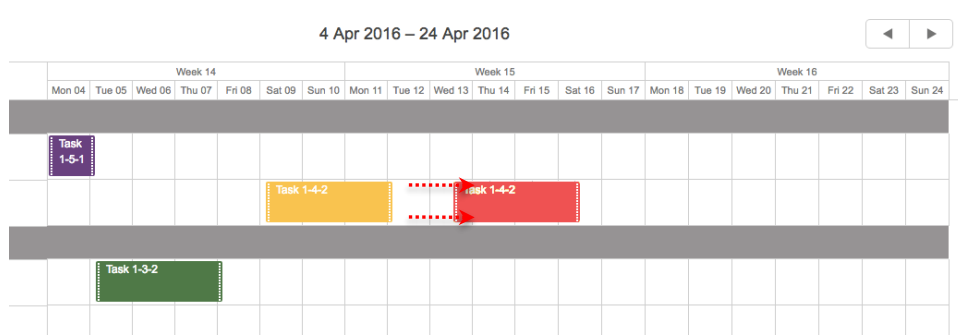
Figure 20 - LPS schedule updated with actuals from field

Figure 20 shows an example where the LPS operation 1-4-2 is delayed by four days, where each row represents a responsible person (or a team) and the x-axis depicts time in days (each box represents a single day). The corresponding task (1-4) is updated in the LBMS schedule (Figure 21) and revised forecast shown to the crew, and an alarm is raised in the LBMS schedule due to this delay. Similarly, if the crew fails to maintain a sufficient level of working backlog and/or there is low level of commitment in the weekly planning meeting, which results in delays in location handover, an alarm will be raised in both the systems.
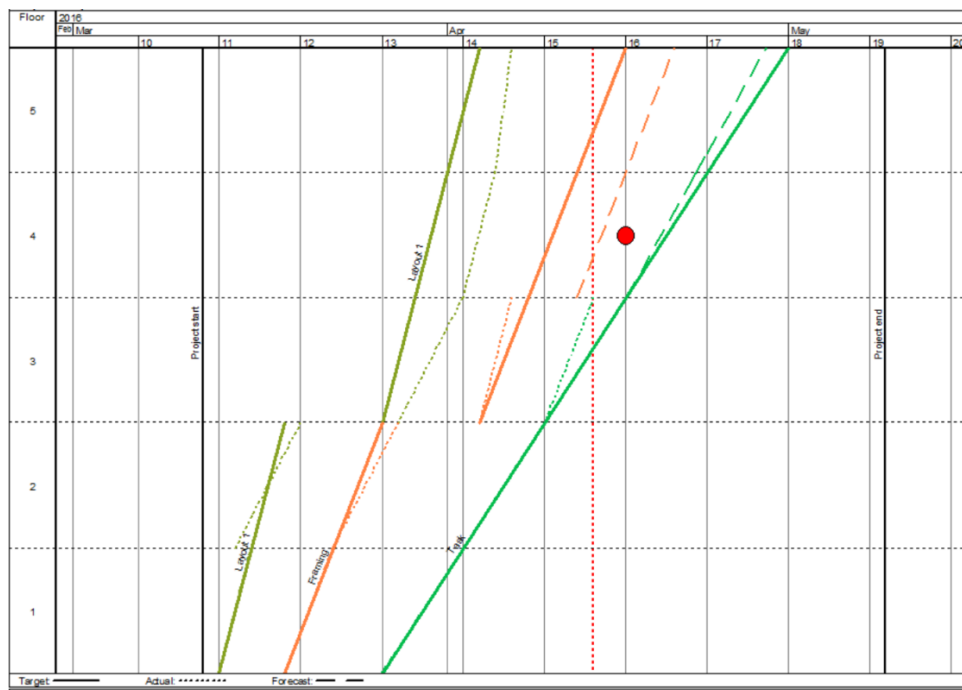

Figure 21 - Updated LBMS Schedule with actuals from the field
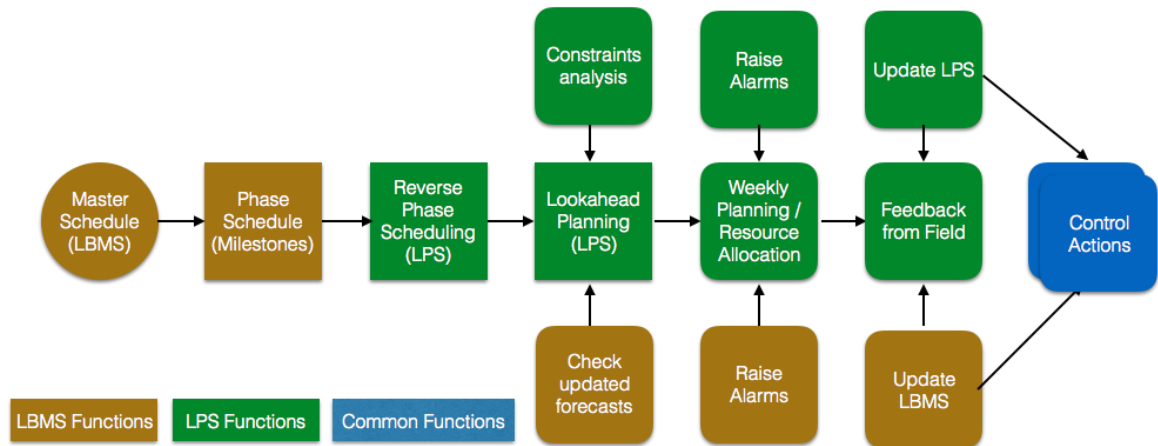
- **PROPOSED COMBINED DATA MODEL**

Figure 22 Proposed Combined Data Model

Figure 22 shows the proposed combined data model. The master and phase schedules are prepared in LBMS and milestones are imported in LPS. The reverse phase scheduling (in a collaborative way) is carried out in LPS and information is updated in LBMS. Subsequently, the constraints analysis and operational level planning is carried out in LPS, while the forecasts are updated in LBMS for potential delays or low-productivity. Weekly planning with resource allocations is taken care in LPS, and actuals are tracked from the field. Both the LPS and LBMS systems are updated with field updates and control actions are initiated from respective systems.

- ## CONCLUSIONS

This research outlines a structured approach to integrate Last Planner System with the Location Based Scheduling System. Through a simple example, the integration between these two systems is demonstrated. By integrating these functions, the workers would have access to both the short and medium term production planning and scheduling information (through LPS) and the impact of the current decisions and statuses on long-term project plan (through LBMS).

The current research is limited in scope, as it has not been validated through real-life case studies. Future research should take into consideration the coding requirements between these two systems and actual pilot implementations on construction projects, to carry out detailed analysis on effectiveness and the need for improvements in the detailed implementation methodology.

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