Location-Based Planning and Controlling methods

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1 Introduction

Location-based management approaches break the project down to physical locations and use the Location Breakdown Structure (LBS) to manage design and production. This makes sense in construction because locations are stationary and thus easy to monitor, whereas crews flow from one location to the next. Because crews are on the move, they are harder to track, although new technology, such as indoor positioning, has the potential to change this in the future.

Location is the basic unit of planning and control in location-based planning. Activity-based systems are based on activities, which can have location coding. In contrast, location-based tasks are formed of similar work in multiple locations. This enables the planning of continuous work and thus emphasizes productivity. Optimally, the same crew can work on the same task continuously without any breaks after finishing work in a location. This is very valuable for productivity because of learning, clarity of schedule to crew members and smaller risks of subcontractor return delays or lost productivity claims. Subcontractors suffer greatly from the standard practice of discontinuous «starts and stops» and prefer to prioritize projects with more continuity.

The Location-Based Management System (LBMS) is a combination of the traditional Critical Path Method and location-based concepts enabling easy planning of continuous work and also easier planning of the logic network by utilizing locations to automate some of the logic relationships. LBMS default planning decision is continuous work and a conscious decision must be made to break continuity. In contrast, CPM scheduled by activities as soon as possible by default and much effort has to be used to plan continuous work. In addition to including an improved CPM algorithm, LBMS also refers to guidelines for planning and controlling which emphasize the productivity of crews and optimizing schedules by aligning production rates. LBMS process starts with the definition of the Location Breakdown Structure of the project, defining tasks and their relationships with other tasks. Then production rates of dependent tasks are aligned and the schedule is optimized. Finally, time buffers can be added between tasks to decrease the impact of variability on the schedule.

As an alternative to the LBMS planning process, takt planning and control has been proposed. Takt is otherwise very similar to LBMS but has a slightly different emphasis. Rather than adding time buffers between tasks, capacity buffers are preferred. As an example of capacity buffer, if the takt time is five days each operation is given five days to complete but in normal circumstances the work should be able to be completed in lower duration, for example four days, leaving Friday as a buffer. Additionally workable backlogs outside of takt areas are used to reduce the risk of crews leaving.

In contrast with activity-based methods, both location-based management methods emphasize the importance of controlling production proactively during construction. Location-based controlling methods emphasize using real-time information and reacting immediately to any problems. LBMS has more of a technical approach and attempts to forecast production to alarm of upcoming production problems well before they happen. Takt operates more socially and issues are elevated immediately when the teams notice that they are unable to meet the takt time. Both approaches put a lot more emphasis on production control and are thus clearly lean techniques based on pull controlling.

The components of location-based planning are presented first, focusing on similarities and differences between LBMS and takt approaches. Then location-based controlling systems are presented. Finally the methods are compared and contrasted to evaluate their strengths and drawbacks based on latest evidence at the time of writing.

2 Location-based planning

The Location-Based management methods (LBMS and takt) both work on the foundation of a location-based plan. This section starts by describing the various components of the location-based plan and then proceeds to visualization of the plan. Logic and calculations related to the LBMS algorithm and takt are briefly described. Risk management and buffers are important parts of location-based plans to protect against variablity and they are described next.

2.1 Location Breakdown Structure

The Location Breakdown Structure (LBS) is one of the most important up-front planning decisions in location-based planning. LBMS allows a hierarchical LBS with unlimited hierarchy levels. For example, the project can first be divided into separate buildings which can then be subdivided into areas, which can be subdivided to floors and then to interior areas. Although most examples of takt in construction focus on single hierarchy level of locations (takt areas), there is no reason why takt would not work also with a hierarchical LBS. However, LBMS has technical calculations which use the different hierarchy levels to create CPM logic automatically but such logic automation has not been described for takt.

There are some differences in how locations are defined between the LBMS and takt methods. Although LBMS guidelines (Kenley & Seppänen 2010) state that at the lowest hierarchy level, the locations should be so small that only one contractor can productively work at an area, takt has in practice taken a more aggressive approach towards batch size reduction. Several documented takt examples include very small takt areas. The smaller the areas, the larger the duration reduction that is achievable by takt. This is one of the key areas of difference: LBMS primarily targets improved productivity and/or decreased risk and takt primarily targets shorter project durations and/or production stability achieved by a scheduling visualization more understandable for the workers. Takt approach also seems to pay more attention into getting areas that have similar work densities. The same principle is also included in LBMS literature but practical use cases have preferred more logical locations even if the quantities change between locations.

The LBS is best determined as a team effort with trade contractors. Especially in interior construction, the definition of LBS benefits from the knowledge of functional testing areas, distribution of cabling from switchboards, the location of shafts etc. The constraints of locations are best known by the MEP contractors, whereas most of the architectural trades are more flexible with their locations. Optimally, the location breakdown structure has already been taken into account during design, so that functional testing areas match the structural areas. Figure 1 shows an example where LBS has been sketched on a floorplan in collaboration with the MEP trades.

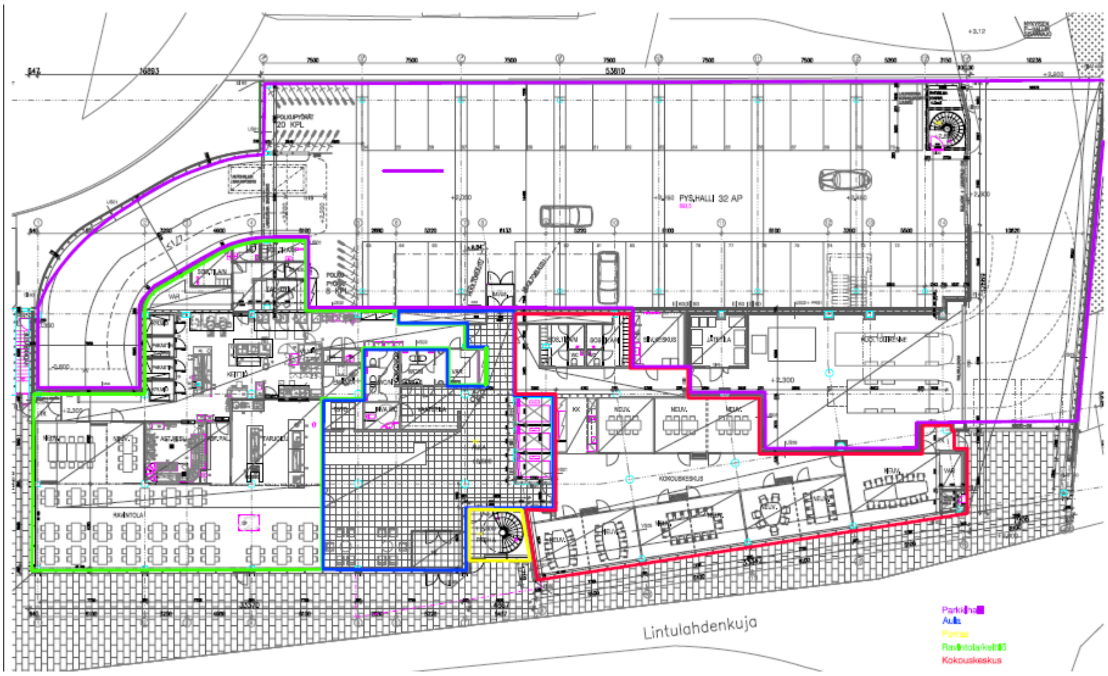

Figure 1. LBS sketched on floorplan. Green area is a restaurant, blue area lobby, red area meeting room area and violet area is parking garage. Stairwell is shown with yellow color.

2.2 Tasks, Location-Based Quantities and duration calculations

In LBMS, tasks are packages of work, which can be completed in a location by the same crew with no breaks and share the same external dependencies to other tasks. Wagons in takt are very similar in concept although takt allows also the work of multiple crews or contractors to be included in the same wagon if the works do not interfere with each others. Both tasks and wagons include work over several locations of the LBS. This is a key difference to activity-based systems, where each activity belongs to a single location.

The work content of a task or wagon is often based on quantities or work densities. The quantities can be defined physically by performing a quantity take-off for each location. This can be automated by using BIM-based quantity take-off systems. Alternatively work densities can be defined in manhours for each location. Regardless of whether quantities or manhours are used as a starting point, the schedule calculations are based on manhours in the end by multiplying the quantities by a labor consumption (manhours / unit).

There are slight differences in how to get from manhours to duration between the systems. Both systems recognize that the duration is a function of manhours, crew size, shift length and potentially some unique difficulty factors allocated to a location. However, LBMS approach prefers to keep the crew size constant and allows the duration to change if there are quantity variations between locations. The takt approach emphasizes uniform takt times in each location. Therefore the duration is kept constant and the crew size or capacity buffer is allowed to adjust if there are quantity variations. The LBMS approach theoretically maximizes productivity (time workers are waiting for work) while the takt approach minimizes time work is waiting on workers. However, takt durations are typically scheduled with less than 100% resource loading (capacity buffers), meaning that if there are no surprises, there is a potential for loss of resource efficiency. This potential resource efficiency loss is mitigated by including in the schedule off-takt areas, which typically include non-repetitive components. Excess resources can work on these off-takt areas which function as workable backlog. In order to minimize the loss of resource efficiency in takt projects, some preplanning effort should be directed towards identifying suitable workable backlog areas with enough work for each trade. However, takt itself is also somewhat flexible, with several different control mechanisms, so in practice it has been found that excessive workable backlogs are not required.

2.3 Flowline and takt visualizations

Location-based schedules can be visualized in flowline or takt diagrams. Both have the same principle. Locations are shown on the vertical axis and time flows horizontally. Time can be either calendar time (default in LBMS) or indicate the takt number (takt 1, takt 2) which is the default approach in takt. Flowline figures show tasks as diagonal lines and the slope of the line signifies the production rate of the task. If the locations do not have any special difficulty factors, the slope of flowline reflects quantity variation between locations. Normally flowlines are drawn from bottom left to top right (Figure 1) although some prefer to draw flowlines from top left to bottom right. The flowlines should normally not intersect because this indicates several trades working in the same location at the same time. Thus, any missing logic can be easily seen in the diagram. Takt diagram shows the same information but rather than using lines, the takts are shown as boxes. Because the takt times are typically constant, the visual look of a takt schedule (Figure 2) is often simpler than in a typical flowline graph where the slopes of lines are changing). In both visualizations, work sequence can be read horizontally and any empty areas indicate optimization opportunities. Compared to Gantt Charts, both location-based visualizations offer a very efficient way of showing information. The quality of schedules can be immediately seen from the visual schedule. Even large schedules can be represented in a single flowline or takt diagram.

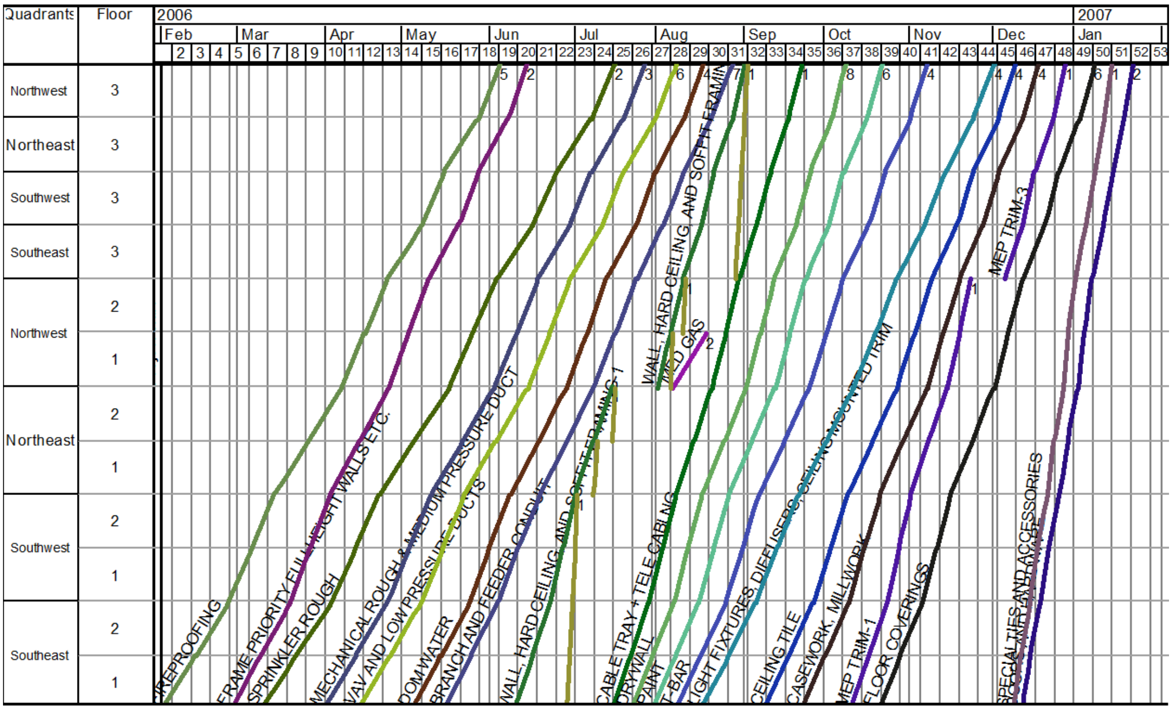

Figure 2: A Flowline figure of a simple medical office building schedule. It is possible to see optimization opportunities by looking at empty spaces between flowlines and work sequence by reading horizontally. (adapted from Seppänen 2014)

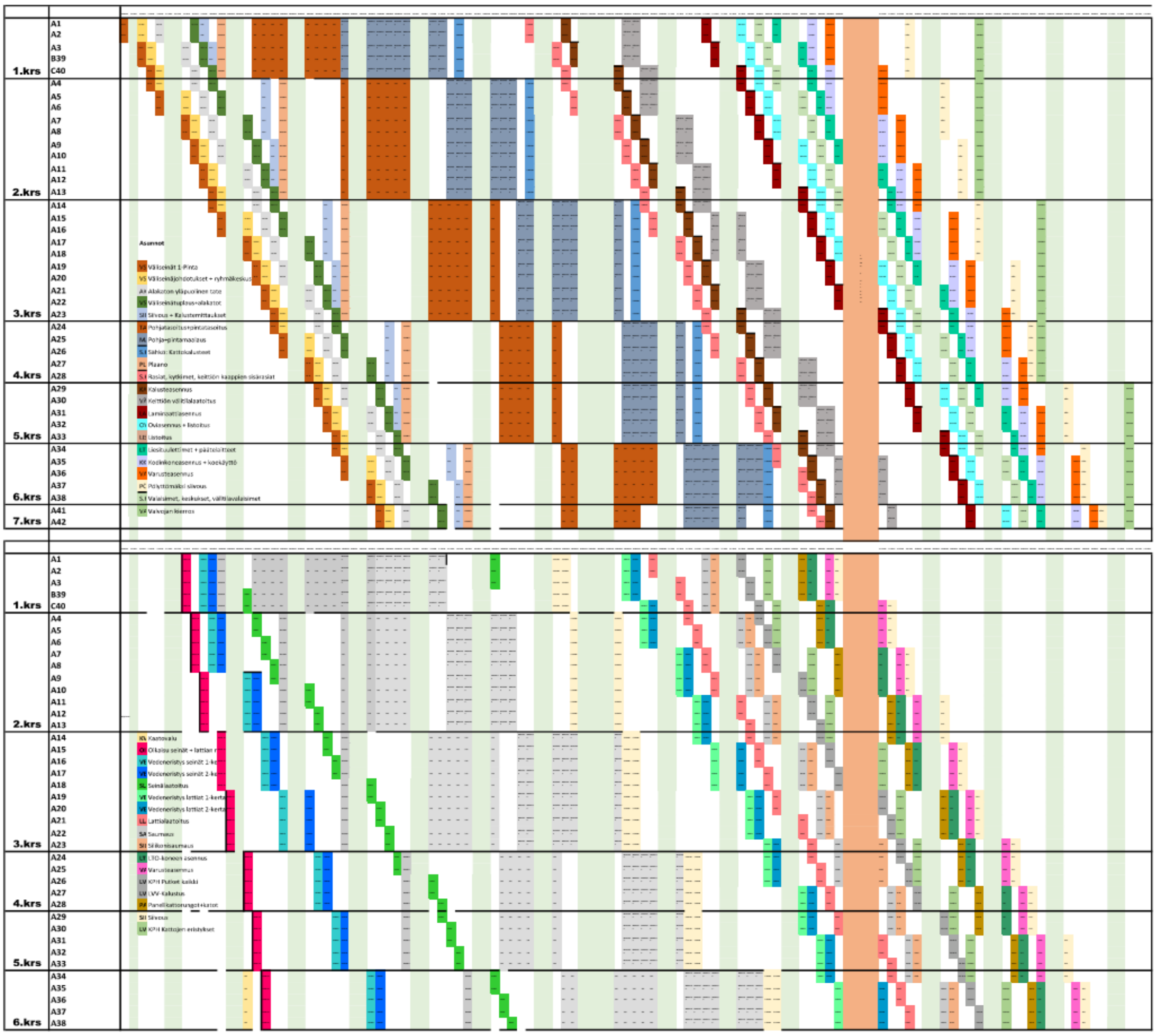

Figure 3: A residential takt schedule. The wagons are colorcoded and shown as boxes. Each apartment is its own location

3 Location-based controlling

Both LBMS and takt approaches give more weight to controlling production than just planning it. Plans are based on assumptions before starting production. The only really accurate data can be observed during production phase. This is in contrast to the "after-the-fact" approach of controlling which is at the core of CPM controlling model. The traditional CPM based model has been called the *thermostat* model of controlling which is overly simplistic.

Controlling in LBMS tends to be a more technical process than in takt. It involves collecting progress data of locations and actual labor on site to calculate actual labor consumption and calculating projections of progress based on actual production rates. LBMS controlling attempts to prevent clashes between different tasks. Takt controlling is based on a more bottom-up approach. There is social pressure to complete within the takt time. The crews are working very close to each other because time buffers are not typically used in takt. They know that missing the takt will cause problems for the next wagon and tend to self-correct their production, raising the issue right away if they know they cannot complete within takt time. However, takt is missing the situational awareness given by LBMS projections. LBMS is automatically updating based on calculations and logic, whereas takt is normally updated using a manual process. Because both approaches have strengths, the combination of LBMS technical calculations and the power of takt social process should be explored in the future.

3.1 Controlling in LBMS

LBMS is more of a technical system which is based on collecting progress data in the form of actual start and finish dates, resources and actual shift lenghts to continuously update actual labor consumption of each task. Actual labor consumption is used to calculate forecasts assuming that work will continue at the currently achieved production rate. When upcoming clashes between tasks are noticed, alarms are shown as visual cues. LBMS controlling is based on preventing the alarms from turning into production problems and potential cascading delays. Alarms are prevented by planning control actions which typically include removing waste to improve productivity or changing of crew size to speed up or slow down tasks or working more or fewer hours. Figure 3 shows an updated flowline schedule with forecasts and an alarm.

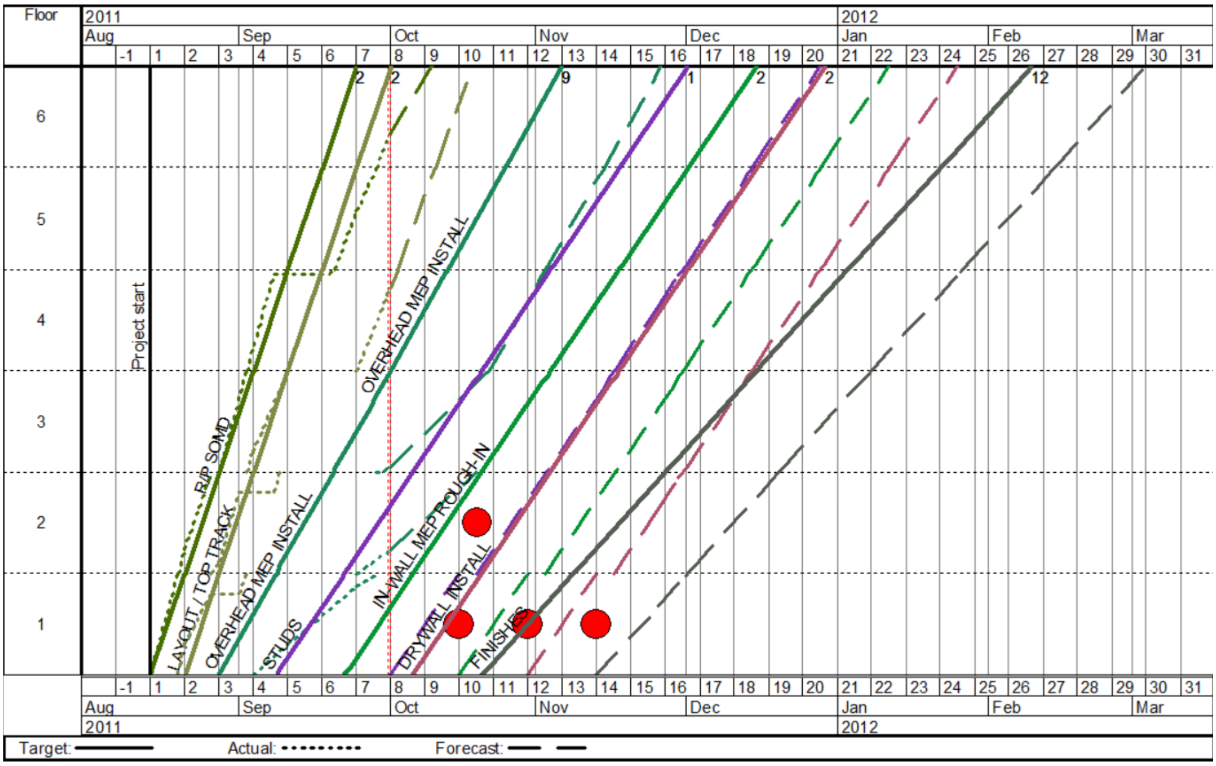

Figure 3: An updated flowlin schedule with progress (dotted lines) and forecasts (dashed lines) and alarms

Key metrics during controlling include production rate index for each task (actual production rate / planned production rate), labor consumption index (actual labor consumption / planned labor consumption), resource index (actual resources on site / planned resources) and degree of completion index (actual percentage completed / planned percentage completed). Degree of completion is often analyzed separately for each trade contractor, construction phase, as well as the whole project.

3.2 Controlling in takt

Controlling in takt relies less on technical calculations and more on social process between actors. Regular, often daily, takt meetings result in immediate actions when takts are not met. Control actions have wider variety than those of LBMS and often include moving scope from one wagon to the next – for example if a trade contractor is constantly missing its takt time, it is possible to leave less important part of the scope to later wagons. By moving scope from one wagon to the next, it is often not necessary to update the schedule at all, just the wagon descriptions. Other possible actions include jumping over takt areas with design issues or stopping the train altogether for major issues. Adjustment actions related to takt have been well described by Binninger et al. (2017). As with LBMS, the plan only offers a framework for performance and is adjusted when there are deviations. However, a technical automatic adjustment process is missing and could be powerful in combination with the more technical LBMS approach. A typical takt controlling KPI is the share of takts completed on time compared to total planned takts.

Figure 4: Takt schedule controlling meeting is more social than the LBMS updating process

3.3 Location-based methods with the Last Planner System

Both LBMS and takt are often combined with the social process of Last Planner System. As was mentioned before, the Location Breakdown Structure is best planned together with the trade contractors. After the locations are known, the pull scheduling process of Last Planner System can be used to identify tasks. The trade contractors can then determine their work density (manhours / area) for each task in each location. Schedule optimization can also be performed collaboratively by starting with each contractors‘ preferred crew and making adjustments until all contractors achieve the same production rate or takt.

Similarly, during controlling, using look-ahead planning and constraint screening of Last Planner System together with the forecasting of LBMS or social peer pressure and transparency of takt, is a powerful combination. Look-ahead planning can be used to ensure that the location-based schedule can be met and updates can be triggered early if it is impossible to achieve the schedule. Weekly commitments can be compared to production rate forecasts and problems can be identified already during weekly planning if the commitments fail to achieve the forecast.

3.4 Training requirements

In order to implement LBMS and takt, some training is required for project teams. Because LBMS is a more technical method, with more centralized control, typically the training focuses on the user of the LBMS software and users of various reports coming from the system. A few days of software training is typically required. The users of the reports (PMs and field superintendents) typically get familiar with the system in a few hour initial training session and the software user (typically a project engineer) helps in interpreting the output in meetings with PM's, field staff and trade contractors. Everyone will gradually get familiar with the system in schedule optimization meetings and when control actions are discussed.

Takt is more decentralized and requires the participation and understanding of everyone to be successful. Typically takt is trained by using various simulation exercises which simulate the real „feel" of a takt project comparing it to traditional projects. A lot of effort is spent to ensure that everyone understands the requirements, including daily huddles where the takt schedules and daily objectives are reviewed with workers. Software training is not that important because there is currently no commonly used takt software. It is more important that everyone understands the principles and how they are expected to behave in a takt environment.

3.5 LBMS and takt approaches compared

The performance of LBMS has been mostly compared with CPM approaches. For example, Evinger et al (2013) analyzed a project where similar work was carried out on different floors of the same project and other floors were managed using CPM and others using LBMS. LBMS floors had 18% higher productivity and achieved 10% higher production rates. The efficiency of LBMS controlling approach was evaluated by Seppänen et al (2014). The research evaluated the impact of production alarms generated by LBMS on production team's decisions in three hospital projects in California. 39% of LBMS alarms resulted in control actions and 65% of actions trying to achieve a higher production rate were successful and achieved an increase of 37% on average. Production problems were also possible to be prevented. The research concluded that by implementing active LBMS based on control, it is possible for the General Contractor to impact trade contractors' production rates and thus decrease project duration. Olivieri et al (2018) evaluated the planning capabilities of LBMS compared to CPM. They found that CPM schedules are not optimal because by just a few modifications in an LBMS environment, it was possible to achieve the same duration as in the comparison CPM schedule but use fewer resources and achieve more continuous and productive work.

Increasingly takt case studies are also being documented. It seems that takt projects can achieve a lot shorter durations than LBMS projects due to the different type of buffering and the social control mechanisms emphasizing peer pressure. The documented projects have not shown increased costs or the waiting hours that could be expected with theoretical comparison. Takt's benefits include that the visualization is easier to understand for crews. For the first time, the entire team can understand the schedule. This makes takt planning and control a quite powerful system which is easy to implement and does not require a special software to run the calculations.

The key difference between takt and LBMS is the preferred buffering mechanism. In LBMS, time buffers are planned between tasks so that there is enough time to react if there are problems. There is enough evidence now to say that this was based on a flawed theory. Time buffers seem to be causing problems because they are separating the workers which decreases social interaction and trust between the teams. Additionally, time buffers are used even if they are not needed because it is difficult to start new tasks earlier than scheduled due to design and material delivery constraints. This needlessly increases project durations. Because the buffers are there, delays are not considered critical and no one takes action. In contrast, in takt projects, there is a constant sense of urgency. Everyone knows that they are expected to hit the takt every time and they need to raise a flag if they cannot do so.

Although takt social process seems to be superior, the LBMS technical process could still have a role to play if it was updated to include takt principles. Takt is currently missing a technical system that could automatically calculate the impact of different control actions when there are deviations from plans. The social process would benefit from some calculations and software that could be used as needed. In the future, the strenghts of the systems should be combined. There is a software for LBMS (Vico Software Schedule Planner) and there are some early attempts to implement takt in software but the current takt softwares still function on top of a CPM algorithm and most companies prefer to use Excel and manual methods.

4 Conclusion

LBMS and takt planning and control are examples of location-based planning and control systems. LBMS has been shown to outperform CPM in both planning and controlling. In fact, the comparison is not fair because LBMS includes the CPM algorithm as a key component. Takt has a lot of similarities to LBMS but emphasizes social components while LBMS emphasizes technical components. Both systems have their strenghts and weaknesses. Takt way of buffering against variability has been shown to be stronger but LBMS technical functions are missing from takt. By augmenting the LBMS technical system to include takt calculations, it would be possible to come up with a combined system where the planners could make choices which strategy is best for each project, or even two approaches could be used in parallel in the same project.

5 Additional reading

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