Schedule margins computation using the Chronographic Logic

Adel Francis[1], and Edmond Miresco[2]

1) Associate Professor, École de technologie supérieure, ÉTS, Department of Construction Engineering, Quebec University, Quebec, 1100, Notre-Dame West, Montreal (Quebec) H3C 1K3, Email: adel.francis@etsmtl.ca
2) Professor, École de technologie supérieure, ÉTS, Department of Construction Engineering, Quebec University, Quebec, 1100, Notre-Dame West, Montreal (Quebec) H3C 1K3, Email: Edmond.Miresco@etsmtl.ca

Abstract:

Delays in the execution of the construction projects may leads to litigation between the contractor and the client. The dispute resolution process analyses and categorizes the delays to excusable or non-excusable and compensable or non-compensable delays. In order to calculate these delays, the planner analyses the impact of the stakeholders' responsibilities and decisions on the schedule and the critical path. One of the points of difference in this case is the traditional question who owns the float? Is it the owner or the contractor?

Prior to analyzing who owns these floats, several questions have to be answered. Which margin has to be chosen? Knowing that there are four types of float, two of them, total and free, frequently used. Secondly, what is the impact of float ownership on the stakeholders and the project? Third, the logic of precedence has several shortcomings that affect the accuracy of the calculation of the schedule and margins. How will we assess the reliability of the accuracy of these calculations? Finally, the more the level of detail increases, the schedule becomes unmanageable; a lower level of detail gives an approximation. How will we assess the effect of this approximation on the schedule calculation?

The Chronographic Method allows the activities split with internal divisions, thus generating new types of floats. This new logic of calculation, combined with the existing margins, have results to the creation of new margin calculation logic which can simulate the real conditions of projects. This paper explains the logic calculation as proposed by the Chronographical logic and integrate the impact of working areas and circulation management. A generalized computing model that simplifies the calculation is also shown. Using this new concept the ownership of margins is discussed.

Keywords: Schedule, Margin, Float, Chronographic, Logic, Construction, Project.

1. INTRODUCTION

Delays in the execution of construction projects may lead to litigation between the contractor and the owner. Delays can be caused by a number of unexpected events during construction, which may increase the required time for work completion or may increase the amount of work that must be completed within a specific period of time (Lorman, 2002).

The dispute resolution process analyzes and categorizes the delays into excusable or non-excusable and compensable or non-compensable delays. The excusable and non-compensable delays cannot be associated with a specific person and include weather conditions, strikes or acts of God. Excusable and compensable delays are caused by the owner, such as excessive changes or non-compliance to deadlines by the owner and his or her team of professionals. Non-excusable and non-compensable delays are usually caused by the contractor due to poor planning and work coordination or improper execution quality. Planners analyze the impact of the stakeholders' decisions on the schedule and the critical path to calculate each party’s level of responsibility for these delays.

During the dispute resolution process, a point of difference is float ownership. Prior to analyzing float ownership, we must define the types of floats and the impact of their use on the stakeholders and the project.

The Critical Path Method (CPM) defines four types of margins. Two of them, Total Float and Free Float, are frequently used. These graphical networks are generally composed of several paths. The Total Float is the maximum margin of a path on the network without delaying the entire project. That means if an activity (or a group of activities) on this path exceeds its Total Float, the entire project will be delayed. If the Total Float of a certain path is equal to zero, all the activities on this path are critical. The Free Float is the margin that an activity has without delaying any other activity. All activities have both a free and a Total Float. The Free Float is always equal to or less than the Total Float. Thus, if an activity consumes its Free Float, it will not disturb any other activities. Beyond this margin, it starts using the Total Float shared with the other activities on the same path and reduces their available margins.

To reduce the risk of delays in the schedule, the contractor may impose margins or time buffering at the end of the project or at some strategic point during the project. Time buffering is one of various buffering strategies, which also include inventory and capacity (Forcael, 2011). Using buffer tasks reduces schedule risk and increases schedule stability (NDIA, 2010). Weaver (2006) said that the approach to margins should be similar to the management of "buffers" in the Critical Chain methodology. Long (2015) stated that floats may belong to the project or to the activity. The use of buffering to reduce risk will then affect float computation accuracy.

Secondly, we must study the impact of float ownership on the stakeholders and the project. According to Keane and Caletka (2008), the float may belong to the contractor, the owner or the project. Strong arguments for each of these three ownership methods, as well as their shortcomings, have been well documented (Householder and Rutland 1990; De La Garza et al. 2007).

Let us analyze why each party wants to own the float. First, the float represents flexibility, and flexibility is important to both the owner and the contractor. Furthermore, it is normal for owners to consider the project their own property and that it should meet their needs. The owner introduced it, funded and will use it in the future, and therefore has the right to make changes during the implementation in order to modify the initial project. One must also understand that owners are generally not experts, and once they see the physical project, their requests will be more accurate. We must add that any changes to the contract will no longer be subject to free competition; they are only done through negotiations. These changes will cost more for the owner, and the contractor who negotiates them will add all the due charges. The contractor will make notable profits and should not have the right to additional compensation. Nor it is not normal that every change to cost more for the contractor; sometimes it is just the opposite. In most cases, changes contain indirect costs which reduce the load of these indirect costs on individual activities. Costs related to the superintendent, leasing offices, health security, etc. generally do not change unless the changes are major.

On the other hand, modifications change the contractor's plans and the coordination of an already complex project. Delaying even non-critical activities increases scheduling risk (NDIA, 2010). Margins are typically used to absorb unavoidable delays in the construction field. Thus, if the owner uses these margins, the risk of an overall delay will increase. In many cases, we should consider that significant delays may occur while making changes due to the time it takes for the client to make decisions and for professionals to integrate the changes into the plans, sketches and specifications. In addition, changes usually involve more than one stakeholder and disrupt ongoing work, affecting on-site productivity. We also have to take into consideration the fact that owners are only concerned with their own project, while the contractor and subcontractors have commitments to other projects. Disturbances on one project can therefore have repercussions on their other projects. The contractor also faces the same problem as the owner in terms of negotiating changes with subcontractors and suppliers. The general contractor has to negotiate any changes with subcontractors and suppliers, and there is no longer free competition, which reduces the opportunity to make more profit with these modifications.

The third plausible option defines the project as the owner of the floats. Thus, according to Wang et al. (2015), courts and board of contract appeals are accustomed to treating the float as though it belongs to the project on a first come, first served basis. However, according to Weaver (2006), delays may be cumulative. This author gives an example in which the client has delayed a non-critical activity. When a second delay was caused by the contractor on a non-critical activity on the same path, the project was delayed. In this case, which party is responsible for damages for late completion, the contractor or the client?

According to Wang et al. (2015), the party that delayed the critical path should take all responsibility, even though this concept may not be accepted by some practitioners. One solution proposed in the literature (Wang et al. 2015 and Weaver, 2006) is to include clauses in the contract to identify float ownership. However, Trauner et al. (2009) disagreed with this concept and stated that it is a mistake to believe that float ownership, if assigned to one party prior to the project's commencement, is a fair or efficient way to resolve potential time-related issues arising from float usage during a project.

Thirdly, we must study the impact of Precedence Diagram Method (PDM) accuracy on margin calculation. PDM and the Arrow Diagram Method (ADM) are the two most recognized methods using the critical path. It is well known that ADM dependencies are defined with more accuracy. The first activity is split into two independent activities; the successor activity cannot start before a sufficient quantity of work is completed on the predecessor activity (Francis and Miresco 2006). However, the PDM is easier to understand and is better suited for construction site scheduling. With its four types of relationships, the PDM allows activities with partial start or partial finish dependencies to overlap, without an obligation to split activities. Moreover, common scheduling software features only the PDM method. Despite its widespread use, we must recognize that precedence logic has several shortcomings that affect the accuracy of schedule and margin calculations. Some studies (Wiest 1981; Badiru and Pulat 1995) have advised caution in using other types of relations than Start-to-Finish. To clarify their position, they gave an example using the reverse critical path, in which diminishing the duration of a critical activity increased the project duration. Others have advised that some types of relations and delays can produce wrong answers when using multiple calendars (Kim and Garza 2005). Francis and Miresco (2006) asserted that the basis of these anomalies is the incorrect use of lags employed with the relationships.

Finally, we have to study the impact of the level of detail on the margin calculation. By default, increasing the level of detail produces an unmanageable schedule, and decreasing the amount of detail gives only an approximation. Weaver (2006) stated that CPM is not an accurate or foolproof determinant of the future. In addition, he also noted that different planners choose different activity patterns to describe the same work, in addition to the fact that the chosen durations are variable, based on presumed resource availability and productivity. The margin calculations by the networks are usually the result of several approximations, including the use of combined levels of detail, employing approximate constraints between activities and the estimation of durations regardless of adequate resource allocation and leveling. Added to all these factors is the precedence method’s inability to include several major management tools. As an example, we can cite on-site circulation, material flow and availability and management of working areas, with all the conflict management issues that these entail.

In summary, existing scheduling techniques generally apply traditional CPM networks for their calculations. These networks use only external relationships between activities and inherit their limits. Precedence logic has several shortcomings that affect the accuracy of schedule and margin calculations. In addition, CPM considers time to be the only constraint for float computation, neglecting several major management tools, such as the management of resources, working areas and circulation on the site. Chronographic logic addresses such limitations by introducing internal divisions and proposing new types of floats.

This paper contributes to the existing body of knowledge by studying float computation using the new concept of margins as proposed by the Chronographic Method. It introduces resources and working areas into margin computation and discusses margin ownership. The principal strength of the proposed method is its relative ability to include realistic computation methods. This paper will work toward the aforementioned goal by addressing two research objectives:

- Research Objective 1: Model realistic types of floats
- Research Objective 2: Study the impact of resources and working area management on float computation.

2. THE CHRONOGRAPHIC METHOD

The Chronographic Method is a time-scale schedule technique that suggests internal divisions of activities according to quantities (Figure 1). Activities can have one or more internal divisions. The activities can be connected on one or more points, called connection points. Internal divisions extend the relationships between the activities to point-to-point relations, generating realistic dependencies and new types of floats (Francis and Miresco 2006).

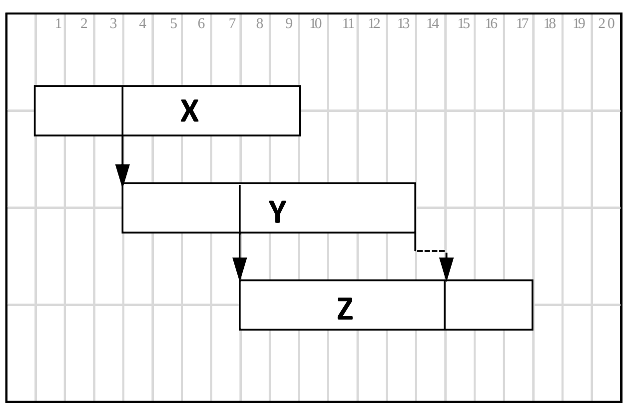


Figure 1. Internal divisions and point-to-point relations

The Precedence Diagram Method defines four types of floats: Total Float, Free Float, interfering floats and independent floats. These floats are based on the premise that every activity is a single integral entity. However, each activity represents an execution process, and its different sections could be affected differently. To represent this reality, the Chronographic Method allows activities to be divided internally, thus generating several new types of floats (Francis and Miresco 2006).

Figure 2 shows these new types of floats. In this figure, all the predecessor activities are identified with the letter "I" and all the successor activities are identified with the letter "J." We can note the following:

1. The Complete Float considers the entire activity to be a single integral entity. No constraints affect its beginning, end or internal sections differently. Activities should possess only predecessors with Finish-to-Start or Start-to-Start relations and successors with Finish-to-Start or Finish-to-Finish relations (Figure 2.a).

2. The Start Float and the Finish Float are created when the beginning and end of the activity are affected differently. Starts (and finishes) should possess the same time predecessor and successor relations (Figure 2.b). In this figure, the latest start of the "J" activity is computed through the maximum lag (drawn as a piston) of its predecessor "I"$_{1.}$ In this case, the Total Float is determined by a predecessor relationship.

3. Partial floats concern every section of the activity and could be Partial Complete Float, Partial Start Float or Partial Finish Float. An activity that has at least one internal relation can have partial floats. Each partial float affects only the section situated between a certain link and the first subsequent internal or external link. The rest of the activity has to depend on its other links (Figure 2.c). In this figure, the upper part shows an example in which no interruption of work is permitted. Thus, the floats are computed for the entire activity, including its start and its end. In the lower part, interruption of work is permitted; the floats are partial and related to the activity sections.

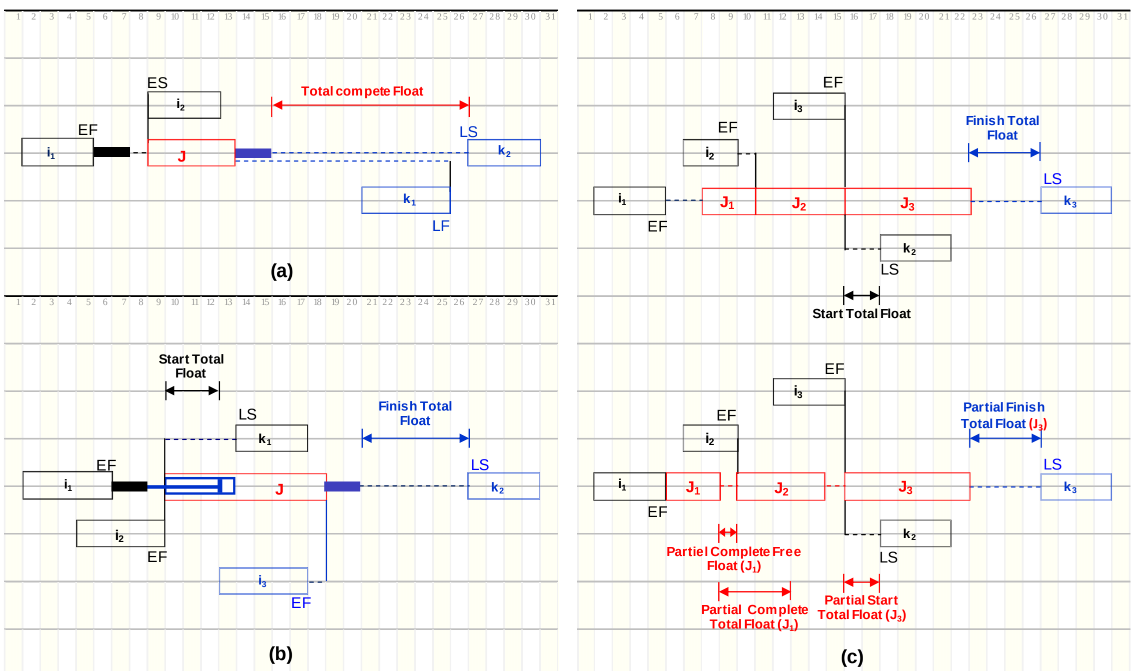


Figure 2. New types of margins

When we add the proposed floats to existing floats, we obtain 24 types of floats. These 24 floats are purely a theoretical classification. Table 1 enumerates these combinations. In real life, only six floats (total and free partial floats) are expected to be used regularly. Independent and interference floats are already marginally used in the industry, and start and finish floats could be computed in the same way as the internal sections (Francis and Miresco 2006).

Including internal workload changes and allowing the use of internal margins will help to simulate real site conditions as closely as possible, providing more realistic results. Research objective 1, to model realistic types of floats, has therefore been fulfilled.

Table 1. Combination of existing and new floats

New Floats	Existing Floats: Total	Free	Independent	Interference
Complete	Complete Total Float	Complete Free Float	Complete Independent Float	Complete Interference Float
Start and Finish	Start (Finish) Total	Start (Finish) Free Float	Start (Finish) Independent Float	Start (Finish) Interference Float
Partial	Partial Complete (Start or Finish) Total Float	Partial Complete (Start or Finish) Free Float	Partial Complete (Start or Finish) Independent Float	Partial Complete (Start or Finish) Interference Float

3. WORKING AREAS AND FLOAT COMPUTATION

3.1 The importance of resources and workspace management

Traditional methods consider time to be the only constraint for float computation. This methodology neglects many important aspects, such as resource availability and leveling, the impact of managing working areas, and circulation. Margin calculations need to consider and manage all these production elements. The interaction between variables, such as availability of labor and equipment, management of limited workspaces, and circulation and flow of materials dictates project duration. Letting traffic occur randomly, without foresight or control, results in loss of time and money caused by congestion and wait times. Effective management should therefore consider all these aspects.

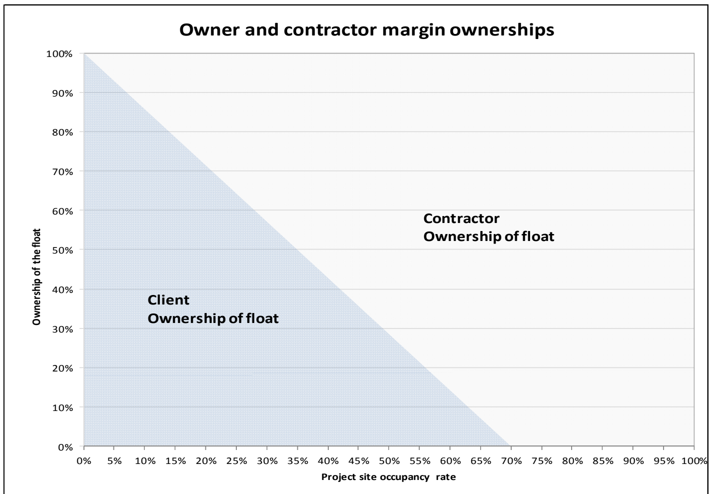
In addition, the management of labor resources regardless of location is inefficient and sometimes misleading, because resources, even if they are available, require the availability of work locations. Otherwise, workspace congestion will negatively affect the circulation of people and materials and reduce jobsite productivity. A schedule that shows activities regardless of their locations overlooks several important aspects of site management. Labor disputes can occur at the site if many activities are scheduled in the same location at the same time. The critical path in this case will be optimistic, and the margin computation will inherit such optimism. Conversely, the underuse of work locations can unnecessarily lengthen the critical path. The critical path that the resource leveling is based on may then be inaccurate. Considering resources and work locations in relation to activities and deadlines becomes paramount. Changes to the contract make the situation worse, because dispute resolution only considers the time factor and ignores resource availability and work site management. These facts made it necessary to address this topic.

3.1 Computing floats by accounting for resources and workspace management

The previous analyses demonstrate that the computation of floats is severely affected by resource and workspace management. The major problem is related to the project site occupancy rate. On a congested site, any changes or additional work will have a significant impact on work progress and will negatively affect resource productivity. Conversely, it is easy to make changes or add work on an underused site with no negative impact. Thus, integrating resources and workspaces into the float computation, as well as their ownership allocation, is of major importance.

Figure 3 demonstrates a curve showing the part belonging to each stakeholder considering the site occupancy rates. This curve considers that the site's maximum occupancy rate is 70%. Beyond this rate, coordination of work becomes more complex due to congested circulation on the site. Numerous space occupancy conflicts may occur, and productivity could decline. If the occupancy rate exceeds 70%, the margins are fully owned by the contractor. If the site occupancy rate is between 0% and 70%, margins will be shared gradually and linearly between the client and the contractor. The contractor's ownership increases proportionally to the site occupancy rate, while the owner's ownership decreases.

Figure 4 shows an example of project planning that considers resources and workspaces. This example schedules the project with a resource-oriented approach. Trimble (1984) mentioned that a resource-oriented schedule is more realistic than an activity-oriented schedule. In this figure, the resources are grouped by location. The figure also shows the percentage of time that different zones are occupied by the resources. For example, in Zone 9, Team 6 occupies 100% of the area from days 6 to 8, while Teams 3, 7 and 2 occupy 80% of the area from days 15 to 27. In this figure, the planner selected Week 11(see the gray cursor on the schedule). The site, occupied during this week by the teams, is shown in the plan view (see the upper part of the figure).



Client	100%	93%	86%	79%	71%	64%	57%	50%	43%	36%	29%	21%	14%	7%	0%	0%	0%	0%	0%	0%	0%
Contractor	0%	7%	14%	21%	29%	36%	43%	50%	57%	64%	71%	79%	86%	93%	100%	100%	100%	100%	100%	100%	100%
Occupency	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%

Figure 3. Owner and contractor margin ownership

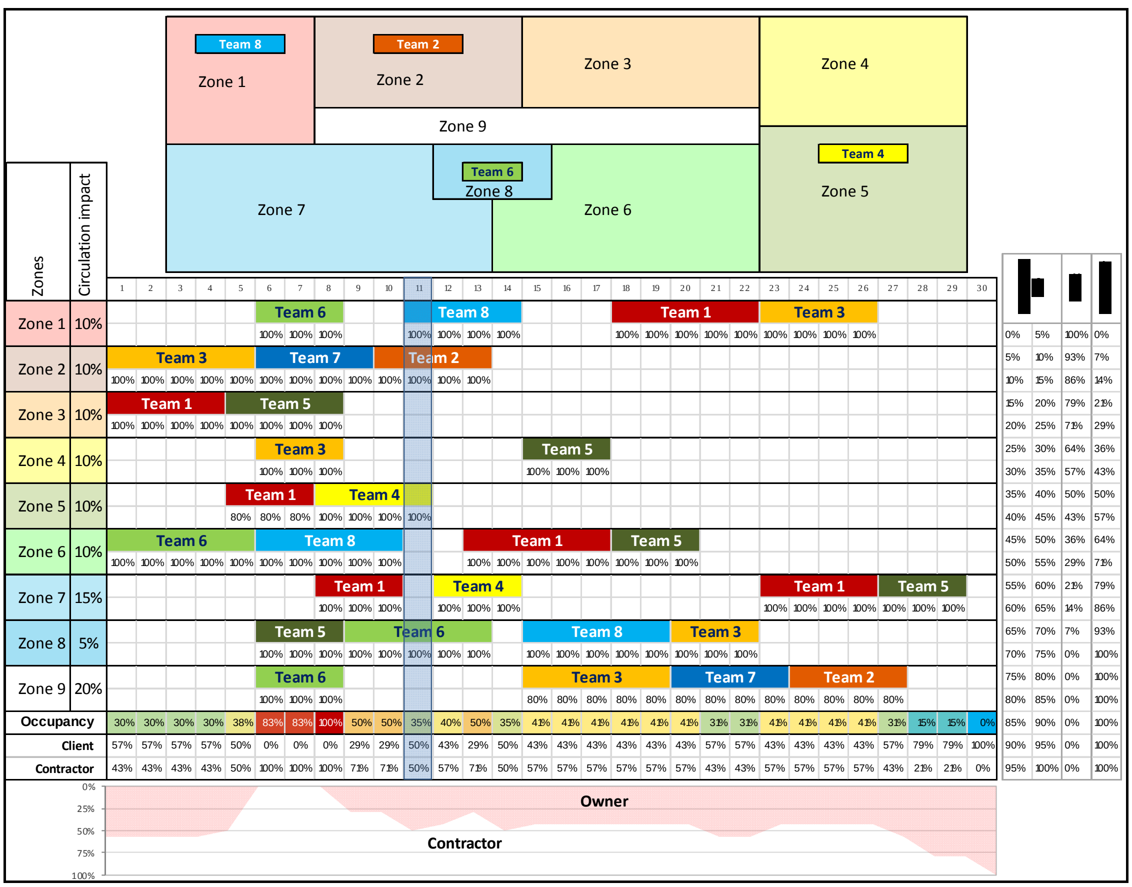


Figure 4. Calculation of the site occupancy rate

In order to calculate the project site's occupancy rate, this example attributes a relative weight to each zone, corresponding to its impact on site circulation. For example, Zone 9 as a corridor represents 20% of circulation, while Zone 8 has only a weight of 5% because its impact on circulation is minor. These percentages are defined by the manager based on experience. Site occupancy is then calculated as the sum of production of the occupancy rates and the zones' relative weight. For example, days 1 to 4 have a 30% site occupancy rate. Using these site occupancy rates, one can divide the floats between the owner and the contractor. In this case, the client possesses 57% of the margins values, while the contractor has only 43% of these values.

Using this methodology, one can share the floats in a realistic manner between the owner and the contractor. For each project, the margin sharing rate could be defined in the contract. Research objective 2, to study the impact of resources and working area management on margin computation, has therefore been fulfilled.

4. DISCUSSION AND CONCLUSON

The dispute resolution process analyzes and categorizes delays and the impact of the stakeholders' responsibilities and decisions on the schedule and the critical path. The accuracy of calculations and float ownership are major issues. During this process, it is difficult to rely on current logic calculations. Despite widespread use, precedence logic has several shortcomings that affect the accuracy of schedule and floats calculations. In addition, these calculations are sensitive to the level of detail variation and neglect several major management tools, such as circulation and working area management.

The Chronographic Method proposes internal divisions of activities, generating new types of floats. This calculation method takes into account the impact of the internal changes on workload and allows the use of internal margins to simulate real site conditions as closely as possible in order to provide more realistic results.

According to Keane and Caletka (2008), the float may be owned by the contractor, the owner or the project. Floats may also belong to the whole project, a certain path or a specific activity. The use of Free Float or Total Float depends on the duration needed to make changes and whether they affect activities, specific paths or the whole project. The impact of margins on stakeholders and projects also has to be considered. A preliminary analysis shows that the project margin must belong to the contractor, while activity margins can be shared. A contractor who finishes earlier saves indirect costs that depend on project duration. Thus, the project float should logically belong to the contractor, who has the right to financial compensation if the owner delays the project completion date. The use of Free Float does not generally increase indirect costs, so these could be used by a stakeholder who needs them, depending on the site condition.

Using resource and workspace management in float computation will increase calculation accuracy. The current method, which accounts only for time, neglects other important aspects, such as site occupancy rates. Before attributing margin ownerships, site occupancy rates should be calculated. Using these site occupancy rates, one can share floats between the owner and the contractor in a realistic manner. The contractor's ownership increases proportionally to the site occupancy rate, while the owner's ownership decreases.

REFERENCES

Badiru, A.B., and Pulat, P.S. (1995). *Comprehensive Project Management: Integrating Optimization Models, Management Principles, and Computers*. Prentice-Hall, Inc. PTR, N.J.

De La Garza, J., Prateapusanond, A., and Ambani, N. (2007). Preallocation of Total Float in the application of a critical path method based construction contract, *Journal of Construction Engineering and Management*, 133(11), 836-845.

Forcael, E., Gonzâlez, V., Ellis, R., Orozco, F. (2011). Conceptual methodology for managing transportation construction projects through the use of buffering strategies. *Proceedings of the 9th Latin American and Caribbean Conference for Engineering and Technology, LACCEI*, Medellin, Colombia, WEI, 1-11.

Francis, A. and Miresco, E. (2006). A Chronographic Method for Construction Project Planning. *Canadian Journal of Civil Engineer,* 33 (12), 1547-1557.

Householder, J. L., and Rutland, H. E. (1990). Who owns float?, *Journal of Construction Engineering and Management*, 116(1), 130-133.

Keane, P. J., and Caletka, A. F. (2008). *Delay Analysis in Construction Contracts*. Wiley-Blackwell, United Kingdom.

Kim, K., and Garza de la, J. (2005). Critical Method with Multiple Calendars. *Journal of construction Engineering and management*, 131(3), 330-342.

Long, R. J. (2015). Contract Scheduling Provisions. Long International, Inc. 1-37website: http://www.long-intl.com/articles/Long_Intl_Contract_Scheduling_Provisions.pdf, accessed on December 22, 2015.

Lorman, S. (2002). An Overview of Construction Claims: How They Arise and How to Avoid Them. *Seminar for Construction Contracting for Public Entities in British Columbia*, October 31, 2002, Clark Wilson LLP.

NDIA (2010). Depicting Schedule Margin in Integrated Master Schedules. WhitePaperFinal, National Defense Industrial Association, Program Management Systems Committee, Schedule Working Group. http://www.ndia.org/Divisions/Divisions/IPMD/Documents/WhitePapers/NDIAScheduleMarginWhitePaperFinal-2010(2).pdf, accessed on December 22, 2015.

Trauner, T. J., W. A. Manginelli, J. S. Lowe, M. F. Nagata and B. J. Furniss (2009). *Construction Delays Understanding Them Clearly, Analyzing Them Correctly*. 2nd ed. Elsevier Butterworth-Heinemann, United Kingdom.

Trimble, G. (1984). Ressource-Oriented Scheduling. *Project Management Journal*, Project Management Institute, 2(2), 70-74.

Trimble, G. (1984). Ressource-Oriented Scheduling. *Project Management Journal*, Project Management Institute, 2(2), pp. 70-74.

Wang, MT., Fan, SL., Tsai, CC., and Chang LM. (2015). A Comparison of Float Ownership Issues for Construction Projects Between Taiwan and China. *Journal of Marine Science and Technology*, 23(1), 69-77.

Weaver, P. (2006). Float – Is It Real? *Proceeding of the Ninth Australian International Performance Management Symposium*, Canberra, Australia, 1-14.

Wiest, J.D. (1981). Precedence Diagram Methods: Some Unusual Characteristics and their Implications for Project Managers. *Journal of Operations Management*, 1(3): 121-30.