How to find Critical Mass of Task Threatening the Projects

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1 Introduction

Modern project management uses a variety of methods that identify tasks and tasks resources potentially threatening the successful completion of the project. From the 1950s to the 1980s, almost exclusively the critical path methods, such as CPM, MPM, PERT (Nicolas, Stein, 2012), and GERT (Pritsker, 1966), were used to identify tasks that delay a project's completion date due to delay of tasks. Based on the results that these methods provide the project managers can draw their attention to critical tasks that need to be monitored in terms of conditions for their implementation, resource allocation and sufficient budgeting. They can also define the potential threats, but the tasks highly uncritical with large slacks are omitted. Newer methods from the last quarter of the 20th century are more focused on the human factor in project tasks completing. Multi-resource tasks, or sequences of tasks with a single assigned resource, are seen as threatening tasks (InterPlan System, 2002). For instance, the Critical Chain method and its derivatives seek to implement project management practices that eliminate human factor influence and, with the use of post-limitation postulates (Goldratt, 1997) warn the project manager of potential project threats or failures. Other methods assessing the importance and criticality of tasks are based on heuristic or the criticalness potential of tasks (Brožová et al., 2016, 2019) measuring task characteristics in terms of cost, resources, duration, connectivity, distance from origin. The higher value of task criticalness potential the higher needed focus on the task.

The first thoughts that small and insignificant tasks that do not lie even not on the critical path, but are present in larger quantities, may also endanger the project due date or successful completion arose at the beginning of 21st century, when the Turnaround "project" Management theory emerges in the context of hurricane Katrina in 2005. The term Critical Mass is used to denote such tasks. In Turnaround context, these tasks concentrated into the critical mass can endanger the project but such tasks are not typical only for turnaround but also for general projects. The critical mass tasks typically do not exceed ten percent of the estimated man-hours, are small, short, inexpensive, low priority, practically without relationships to other tasks, with only few resource assignments. Even though the critical path tasks are on schedule, critical mass tasks generally have plenty of float (slack time) and can be executed just about any time in any order. Nevertheless, insufficient resources often force these tasks to be scheduled late (InterPlan Systems, 2002). The omission or neglect of one of these tasks may not jeopardize the whole project, but grouping them in the critical mass will endanger the project in its very essence.

Typical examples of such tasks are various control or verification tasks, but also performed routinely tasks, many times per project, which are normally performed only a few times instead of the scheduled number of repetitions. Therefore, we try to derive indicators that can reveal these tasks using the indicators values or similarities of these values.

2 Critical Mass Potential and Routine Tasks

The Critical Mass Member Candidate (CMMC) tasks may endanger the project itself or its crucial parts. As mentioned above, tasks of this type are often short and inexpensive, isolated, can take place at any time, and have no or few successors. The starting points of suggested method of identification of the critical mass task are the criteria and indicators following the specific features of critical mass tasks and the reversed concept of criticality. Next the task neglectedness potential of the project tasks is estimated using the multiple attributes decision-making method similarly the tasks criticalness potential (Brožová et al., 2016, 2019, Šubrt et al., 2019).

The first criterion for this assessment is the continuity criterion based on the degree of isolation of the task. The number of successors of the project task is crucial for its determination. The predecessors do not play an important role; there is no control mechanism for initiating the next task for predecessors. Suppose the project is formalized by an Activity On Node network graph. Then the continuity criterion can be derived from the output degree of the task node. Although it is significant for all relationship types, the major impact is in the case of FS relationship. If the output degree is greater than 2, sufficient successors can be assumed to control task completion, in the opposite site, there is lack of control of task completion. The 1 is added as each task has at least one successor – the dummy tasks “end of the project”. The continuity criterion was set as

$$ci_i = \frac{deg_{out}i + 1}{2} \tag{1}$$

where ci_i is criterion of task continuity, $deg_{out}i$ is output degree of the node i. This criterion for the CMMC tasks is relevant if and only less or equal to 1.

The second criterion showing another view on potential task neglectedness combines the criteria of resource diversity and resource intensity. Again, it is considered that CMMC tasks are not resource intensive or resource variable. The analysis shows neglect threating, if no more than two resource types and/or no more than two assigned units appears. Criterion of resource variability is

$$crv_i = \frac{k_i}{2} \tag{2}$$

where crv_i is criterion of resource variability, k_i is number of resource types assigned to task i. Value of this criterion is CMMC relevant if and only if less or equal to 1.

Criterion of resource intensity evaluates the amount of resources units as

$$cri_i = \frac{\sum_{k=1}^{s} r_i^k}{2} \tag{3}$$

where cri_i is criterion of resource intensity, r_i^k is number of resource units assigned to task i, k is number of resource types assigned to task i, s is number of resource types assigned to task i. This criterion is relevant if and only if less or equal to 1.

These two criteria can be combined to the resource neglectedness criterion using their product

$$cr_i = crv_i . cri_i \tag{4}$$

This criterion is again CMMC relevant if and only if less or equal to 1.

Next criteria for evaluation of CMMC are directly derived from the factors based on the project schedule, and are compared with the aggregate indicators of the entire project (total duration, budget, total work effort) for normalization of its values. The reason for this is to eliminate the influence of dominant task and identify the tasks with minimal demands. Therefore, we can define four additional criteria:

The CMMC are tasks that are generally very short. Therefore, the duration neglectedness criterion of the Critical Mass task has to reach very low value

$$ct_i = \frac{t_i}{T} \tag{5}$$

where ct_i is task duration neglect criterion, t_i is duration of task i, T is total duration of the project.

Task cost neglectedness criterion also has to have very low value if the Critical Mass tasks are really inexpensive

$$cc_i = \frac{c_i}{C} \tag{6}$$

where cc_i is task cost neglect criterion, c_i is cost of task i, C is project budget at completion.

Task work neglectedness criterion describes the needed effort which is very low for the Critical Mass tasks

$$cw_i = \frac{w_i}{\sum_{i=1}^{N} w_i} \tag{7}$$

where cw_i is task work neglectedness criterion, w_i is amount of work of the task i, N is the number of tasks in the project

The task neglectedness criterion of the slack has a special position among the neglectedness criteria. It is based on the idea that CMMC are tasks that can be performed practically any time during project timespan, thus having a large total slack with respect to the duration of the project so the value $\frac{s_i}{T}$ is high. Therefore, the slack neglectedness criterion is

$$cs_i = 1 - \frac{s_i}{T} \tag{8}$$

where cs_i is task slack neglectedness criterion, s_i is total slack of task i, T is total duration of the project. This criterion is CMMC relevant if and only if less than 1.

The procedure of the analysis of the Critical Mass of the project has three steps:

In the first step the possible CMMC tasks are selected using the aspiration level method from all project tasks. These are all tasks with all values of continuity, resource variability, resource intensity and resource neglectedness criteria smaller than 1.

In the second step the CMMC potential is calculated using Simple weighted additive method so that the highest value means higher potential

$$CM_i = 1 - (u_1 ct_i + u_2 cc_i + u_3 cw_i + u_4 cs_i) \;\; i = 1,2,..,N \tag{9}$$

where CM_i is global evaluation of the CMMC task potential, u_1, u_2, u_3, u_4 are the weights of partial criteria. The tasks with the higher Critical Mass potential are identified as possible Critical Mass tasks which would be the tasks whose duration, cost, work and slack neglectedness criteria have a lowest value (Šubrt et al., 2019).

The setting of individual criteria weights for this concept is not clear and easy. According to practice, the slack and duration neglectedness criteria are probably the most important, but this cannot be generalized.

In the third step the similarity of the tasks with higher Critical Mass potential is checked. The routine of tasks is situation when the tasks are repeated several times during a project progress in the same or analogous form. The routine is considered an essential feature for determining the Critical Mass and is quite difficult to capture, because in practice, these tasks does not have to be named identically (Substation Test 1, Substation Test 2, …), or assigned the same resources (revision technicians, …).

Each task is represented by vector of its evaluation according to the neglectedness criteria, so the task routine matrix is obtained, each task is in one row.

$$TRM = \begin{pmatrix} ci_1 & crv_1 & cri_1 & ct_1 & cc_1 & cw_1 & cs_1 \\ ci_2 & crv_2 & cri_2 & ct_2 & cc_2 & cw_2 & cs_2 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ ci_m & crv_m & cri_m & ct_m & cc_m & cs_m & cs_m \end{pmatrix} \tag{10}$$

where *TRM* is task routine matrix, m is a number of possible CMMC tasks.

We suggest to use the Saaty's compatibility index (Saaty, Peniwati, 2007) to investigate the similarity of potentially CM task. For two tasks T_i and T_i the compatibility index is calculated as

$$S_{ij} = (\frac{1}{n^2}) e^T A_i \otimes A_j^T e \leq 1.1 \tag{11}$$

where the elements of matrix A_i is calculated as pairwise comparisons matrix which consists of all ratios of every two elements from task i evaluation vector and $\otimes$ is the Hadamard product of matrices. If $S_{ij} \leq 1.1$ the tasks can be assumed as recurring (routine) tasks with neglectedness potential. The more lines in the TRM are compatible, the more routine tasks can be supposed in the project.

3 Example

The Critical Mass approach provides relevant results for larger and large projects, because the possibility of neglecting the timely execution of any task is small for small projects. However, let's assume the following small-scale project whose indicators, as well as the time schedule (Gantt Chart), are created using MS Project (Figure 1).

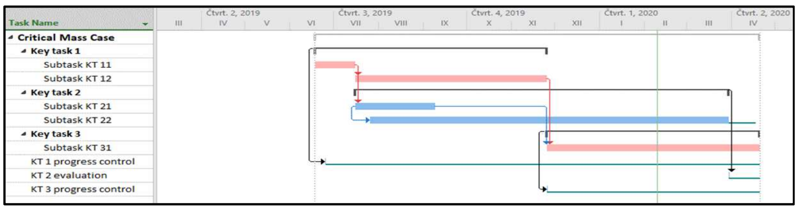

Figure 1 Example: Critical Mass Project Gantt Chart

All the tasks have assigned resources and work and all the resources are rated. Summary durations, costs and work parameters together with neglectedness criteria are presented in the following table (Table 1). For summary tasks the neglectedness criteria have no meaning.

Step 1: If continuity and resource criteria are bigger than one, the corresponding tasks are not supposed to be the critical mass tasks.

Step 2: Evaluation of the last column in Table 1 – Critical mass Potential – shows, that the highest risk of neglecting has “KT 1 progress control”, followed by “KT 3 progress control” and “KT 2 evaluation”. In case of bigger project, such type of tasks can potentially form a Critical Mass threating the project as a whole. The lower neglectedness potential has the task KT 11.

Task Name	Duration in dys	Total slack in dys	Cost in CZK	Work in hrs	Number of resources	Number of resource units	Number of successors	cii - izolovanost	crvi - počet zdrojů	crii - počet jednotek	cri	cti - délka	cci - náklady	cwi - práce	csi - rezerva	**TASK NEGLECT POTENCIAL**
Criteria weights								*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	*0.125*	
												0.25	*0.25*	*0.25*	*0.25*	
Critical Mass Case	**218.88**	**0**	**13351080.00**	**8876**												
Key task 1	**113.88**	**0**	**3292160.00**	**1822**												
Subtask KT 11	20	0	288000.00	320	2	2	1	1	1	1	1	0.0914	0.0216	0.0361	1	0.7128
Subtask KT 12	93.88	0	3004160.00	1502	1	2	2	1.5	1	1	1	0.4289	0.2250	0.1692	1	
Key task 2	**183.88**	**14.95**	**6446480.00**	**4532**												
Subtask KT 21	38.88	14.95	466560.00	311	1	1	2	1.5	0.5	0.5	0.25	0.1776	0.0349	0.0350	0.9317	
Subtask KT 22	175.88	14.95	5979920.00	4221	2	3	0	0.5	1.5	1.5	2.25	0.8035	0.4479	0.4756	0.9317	
Key task 3	**105**	**0**	**3612000.00**	**2520**												
Subtask KT 31	105	0	3612000.00	2520	2	3	0	0.5	1.5	1.5	2.25	0.4797	0.2705	0.2839	1	
KT 1 progress control	0.1	213.78	2000.00	0.8	1	1	0	0.5	0.5	0.5	0.25	0.0005	0.0001	0.0001	0.0233	0.9940
KT 2 evaluation	0.05	14.95	1000.00	0.4	1	1	0	0.5	0.5	0.5	0.25	0.0002	0.0001	0.0000	0.9317	0.7670
KT 3 progress control	0.07	104.93	1400.00	0.56	1	1	0	0.5	0.5	0.5	0.25	0.0003	0.0001	0.0001	0.5206	0.8697

Table 1 Example: Task parameters and indicators

Step 3: Now the similarity among the selected tasks is checked using Saaty’s compatibility index. Only two task seems to be routine tasks - “KT 3 progress control” and “KT 2 evaluation”. Its compatibility index is 1.086.

4 Conclusion

Sometimes it happens that there are tasks in project management practice which seem to be not important. However, projects are sequences of tasks having an irreplaceable role and their failing or neglect may have fatal consequences, could endanger the whole project or significantly reduce its quality. The procedure proposed in this article allows to identify and analyse such tasks on the basis of the neglectedness criteria and neglectedness potential. The procedure allows to identify the critical mass task is also designed. Our approach should help project managers to have a wider and more diverse set of tools that make project management increasingly complex without distinguishing between complex and complicated.

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