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CRUSHING CONSTRUCTION PROJECTSBY RELOCATING RESOURCES

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ABSTRACTA variety of schedule compression techniques are used to get delayed construction projects‘‘backontracks’’.Thispaperpresentsanewoptimizationapproachtoschedulecrashingbyrelocating someof the workers from non-critical to critical processes (changing composition of crews using the initial poolof workers) and employing additional resources. The authors describe their idea in the form of a mixed-integer linear problem. A numerical example illustrates the merits of the proposed approach. The methodmaybecomeapracticalsupportinconstructionschedulingdecisions.

I.INTRODUCTION

Construction projects constitute a particular challenge formanagers. The factors that contribute to their unpredictabil-ity include the susceptibility of construction processes toweather,uniquenessofdesigns,highemployeeturnoverrates, various supply-related logistic problems, and high plantfailurerate[1]–[9].Whiletheseprojectsarecommonlyunderstoodasexcep-tionallydifficulttodeliverontime,projectownersarerigor-ousaboutdeadlinesspecifiedinthecontract.First,theyneedtoconformtothebankloanconditions(schedulechangesarenotwelcome,especiallyintermsofpostponingthecom-pletiondate).Second,theclientsdesiretobenefitfromtheprojectsasquicklyaspossible.Therefore,theytendtosetshortandfixedduedateswithnotoleranceofthe‘‘unex-pectedobstacles’’likelytobeencounteredbythecontractor.Given limited project budgets, short times for completion,scarcehumanresources,andhighrisk,theproblemofcom-pressingconstructionschedulesisfarfromtrivial.Thewell-establishedmethods,suchasCPM,PDM,LSM,PERTproveinadequateforsuchchallenges[10]–[19].Especiallywithrepetitive projects, the main disadvantages of these methodsareimprecisevisualization(evenwithsmallprojects,thebarchartsornetworkdiagramsaredifficulttohandle)andfailuretocapturethecontinuityofworkandthedynamicsofproductionrates[12]–[14],[20]–[22].Inappropriate scheduling methods and tools mean morethantheplanner’slackofcomfort:theyimplyoversimplifica-tionsandomissions.Theseresultinschedulingerrorsandthecontractor’s accepting unrealistic deadlines. What follows arecontractual penalties, the client’s disappointment, and harmto the contractor’s reputation. Inadequate scheduling tools failto prevent the planner from misallocating resources, and theresulting workflow disturbance reduces labor productivity,increases the cost of works, and damages the workforcemorale. For this reason, the research and project manage-ment community strives to develop more practical planningmethods.The authors attempt to provide a tool to assist construction managers in scheduling fast-track projects as well as incrashing schedules to make up for delays. The idea is to allowmodifications of crew composition, so using some membersof crews performing non-critical processes to reinforce thecrews busy with critical tasks. This way, the critical taskscan be delivered quicker, though at the expense of othertasks.Theoverallprojectdurationisreduced,whilethepoolof resources stays fixed. However, for greater flexibility,employingextraresourcesisalsoallowed.

Thenoveltyoftheapproachconsistsinthefollowing:

- The model assumes that the crews can be split into teamsand stay operational even if a team is relocated to othertasks. A typical assumption in construction schedulingis that of fixed crew composition. This approach mayfoster the learning effect. However, if crews are com-posed of a number of teams, and allocated to a task ofsmallworkload,theirworkbecomesinefficient.Itisthusconsidered practical to allow transferring out a part ofthecrewanduseitefficientlyelsewhere.
- Theproposedapproachintegratestwoconceptsofproject crashing – by employing extra resources (sub-contracting), and by relocating in-house resources. Theidea of relocating teams helps reduce the project dura-tionwithnoneedtohireadditionalresourcesorchangeconstruction methods to faster but more costly ones. Thisway,accelerationgeneratesnoextracost.
- The idea of setting the upper limit to the cost of sub-contracted works helps manage in-house resources ratio-nally. Many existing models for schedule crashing relyon subcontracting (increasing the resource pool). Theyconsider the direct cost of subcontracting but ignorehidden costs associated with reducing the productivityofin-houseresourcesandtheirstandbypay.

The paper is organized as follows: the next section provides anoverviewoftheschedulecompressionmethodspresentedin the literature. Then, the authors propose their approach toreducingprojectduration:theassumptionsaredescribedandthe optimization model is mathematically formalized. Furtheron,themodelisappliedtoasimplenotionalcasetoillustrateits merits. The last section summarizes the results, discussesthe limitations of the model, and indicates directions forfuturework.(Vasanthy and Jeganathan 2007, Vasanthy et.al., 2008, Raajasubramanian et.al., 2011, Jeganathan et.al., 2012, 2014, Sridhar et.al., 2012, Gunaselvi et.al., 2014, Premalatha et.al., 2015, Seshadri et.al., 2015, Shakila et.al., 2015, Ashok et.al., 2016, Satheesh Kumar et.al., 2016).

II. LITERATUREREVIEW

For practical reasons, minimizing project duration is prob-ably the most frequently addressed problem in constructionproject scheduling [23]–[34]. The body of literature on fast-track project planning and schedule crashing techniques isrich. The methods can be roughly divided into the followinggroups:

Usingassembly-lineapproachandasteadyrhythmof work of crews (to eliminate disturbance in the flow ofworksandeliminateunproductivetime) addingextraresourcesorchangingtheexecutionmodesof selected processes (to quickly complete the key pro-cessesthataffectprojectduration), Usingflexibleprocessesprecedencerelations, allowingsomeprocessestobesplitforgreaterflexibilityit breaks down complex processes into simple repetitiveactivities that may be performed by specialized crews, andfocuses on continuity of their work: allows them to move fromone unit to another without interrupting the work of otherspecializedcrews[17],[35],[36]. A number of methods based on this idea were developed,for instance RSM by Harris and Ioannou [19]. The authorsintroduced the concept of the controlling sequence, whichhas the same practical significance as the critical path in theCPM method and can be used to determine the duration of aproject.YangandIoannou[37]computerizedtheRSM,thusprovidinguserswithameanstoquicklytestvario usschedul-ing strategies. An interesting development of this idea wasproposed by Maravas and Pantouvakis [38], who created afuzzyRSM.Possibledifferencesbetweenrepetitiveunitsandthevariationincrewperformanceweredescribe dintheformof fuzzy sets to allow for their naturally non-deterministiccharacter.(Manikandanet.al., 2016, Sethuraman et.al., 2016, SenthilThambi et.al., 2016).

A]*SPLITTINGPROCESSES*

Another way to compress schedules is to allow some non-criticalprocessestobesplit.Astheirexecutionissuspended,theirresourcescanbetemporarilyredirectedtoreinforcethecrewsperformingother,criticalprocesses.Thisway,thecrit-icaltasksmaybeacceleratedandthewholeprojectdeliveredfaster. The disadvantage of this solution is a possible extracost and work to protect the effects of unfinished processesagainstdamage.ThemodelpresentedbyAltuwaimandEl-Rayes[58]allowedinterruptingsecondaryconstructionprocessestoreduce the overall project duration and to improve the con-tinuity of works. Their procedure consisted of four phases:earlyschedulecalculation,work-continuityfloatcalculation,ensuring strict work continuity, and assessing schedule per-formance. The merits were illustrated by an example of arepetitiveproject.Themodelenablestheplannertogeneratea wide range of schedules with a reduced completion timeandanalyzethemintermsofthetotalprojectcost.

Similarly, Long and Ohsato [59] considered splitting andsuspending tasks of repetitive projects to create scheduleswith minimized time and/or cost. Their method respects allconstraints of the initially defined network model and con-straintsonresourcecontinuity.Therelationshipsbetweenthetime and cost of processes can be linear, nonlinear, or dis-crete. The method's performance was demonstrated usingexamples of the construction of a bridge (a case used fortesting in other publications) and a notional project consist-ing of five work units with eighteen processes in each ofthem. Amini and Heravi [60] developed a model that allowsinterrupting processes with higher production rates to allocatetheir resources to other processes in order to reduce projectduration. The presented method is flexible in terms of thenumber and duration of pauses in the course of the processexecution – they can be defined according to the planner'spreferences.

CONCLUSION

Managing construction projects is a challenge and, due tothe sheer scale, the consequences of wrong decisions areparticularly costly. Unfortunately, the standard schedulingmethodsarenoteasilyadaptabletotheproblemsofconstruc-tion projects. The need for reliable decision making supporthas not been satisfied yet. The existing ways of acceleratingconstruction projects (allocation of additional resources, theintroductionofsoftrelationsbetweenprocesses,enablingtheinterruptionofsecondaryprocesses)usuallyentailadditionalcosts. This paper puts forward a MILP algorithm for compressingschedules by changes in the resource allocation – namely bysplitting crews into teams and relocating teams to processesthat are reasonable to be accelerated. Team relocation wasobservedintheconstructionpractice,thoughnotfoundtobe reflected in schedule optimization algorithms describedintheliterature.Afurtherreductionofconstructiondurationwas also enabled through subcontracting. Both methods wereincorporatedintooneoptimizationmodel.To illustrate the merits of the method, it was applied tooptimizeatestschedule.Thetotaldurationwasreducedby 7% without employing extra resources. However, as thepool of resources was increased by subcontractors, the sched-ule was compressed by as much as 27.7% of the originalduration, though with a considerable increase in subcon-tractingcosts(40%).Thedevelopedmethodgeneratedbetterresults than another state-of-the-art method taken from theliterature.These results, though certainly not representative, show thepotential of this method. It significantly increases flexibilityin resource allocation. It may be applied for re-schedulingdelayed projects to find a way to accelerate while beingconstrained by a fixed pool of resources. The method canalso be used by contractors at the bidding stage to analyzehow to make the best use of available resources and how tosubcontract more economically

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while meeting the contractualdeadlines.Obviously,theexamplewepresentedwasrelativelysmall,butthemethodappliestoreal-lifefull-scaleproblems.Avail-able solvers of linear models are efficient even if there arethousands of constraints.

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