**Ain Shams University - Faculty of Engineering**

**Department of Structural Engineering**

# Optimizing the Duration of the Construction Projects in Egypt by Using Goal Programming

Thesis Submitted in Partial Fulfilment of the Requirements of the Degree of

**"Master of Science in Civil Engineering – Structural Engineering"**

Submitted by:

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**March 2017**

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# ACKNOWLEDGMENT

First, thanks to ALLAH, God of all, for everything happened in my life, who gave me the knowledge, courage and patience to accomplish this research. May the peace and blessings of Allah be upon Prophet Muhammad (PBUH).

It is my great pleasure and honor to have "Prof. Ibrahim Abdulrashed Nusair" and "Prof. Niveen Mohammed Khalil Badra" as my thesis supervisors, who supported and guided me throughout my research and offered their precious time, experience and advice.

All the credit to my father ‘’ Prof. Adel Belal ‘’ for his supervision and providing me the strength to continue and sharing his experience to ensure the quality of the content.

Special thanks to my mother, wife, and family for their support and encouragement to achieve my target in this thesis.

Moreover, I would like to thank "Dr. Mohammed Hassan" (PhD holder in Syria) for his care and valuable support during my research.

Special thanks go to "Eng. Khaled Mahmoud’ who supported me with the real-life experience in the Construction field, and provided me with all data required during my research.

# ABSTRACT

Construction project`s duration and cost are critical elements in the economy of today`s market. The relationship between the project duration and cost is called time-cost trade-off analysis or decisions. Time-cost trade-off is very important to crash the activities that lies on the critical path to achieve the project deadline duration.

Existing techniques and strategies that deals with time – cost trade-off issue, which is involved in planning the projects, have concentrated and focused on basic approaches that does not represent construction project in reality, such as generalized activity precedence relationship, external time constraints, milestones for particular activities, quality considerations, resource availability and also bonuses and penalties costs.

The aim of this thesis is to develop a mathematical solution method considering some of the additional realistic project characteristics mentioned above, which are generalized activity precedence relationship, external time constraints, milestones for particular activities and also bonuses and penalties costs.

In this research, a method will be proposed and utilized which depends on a linear relationship between cost and time for each activity and generates the optimum time–cost curve of the project and the minimum cost schedule by using goal programming to look for the minimum deviation from the target either time or cost. Evaluation results indicate that the method can be reliably applied to engineering projects.

Two projects have been studied; first one is a project of upgrading an existing road of two-lane undivided highway into a four-lane road with applying controlled traffic access. The second one is the construction of Cairo Airport Terminal Building 3, known as Seasonal Hall.

The construction management team for both projects already performed crashing analysis to reach optimum cost corresponding to the desired time. The construction team did not take into their consideration all the factors mentioned above.

The proposed model proofed that it can be very useful in construction projects to find better solutions for crashing the activities. Solution curves also have been generated to help the decision makers for taking the right decision and see how flexible they are in extending and reducing the time of the project and its corresponding cost.

All decision makers will be able to see how each solution deviates from the target of the client in both time and cost. In the proposed model any positive deviation means more time or cost than the target. Hence, the proposed model is targeting the minimum deviations, any negative deviation means less time or cost than the client even requests.

For the first project, the model solution could meet the desired project duration and budget, and even finds better solutions which found to be 3 days earlier which represents 4% of the project duration, while saving is about $700 which represents about 1.57 % of what the project team proposed for the completion cost.

For the second project, the model solution could meet the desired project duration and saves about L.E 53000 which represent about 1.32 % of what the project team proposed for the completion cost.

**Keywords:** Time-Cost Trade-off analysis, Goal Programming, Parametric Mathematical Modelling, Crashing, Optimization.

# DECLARATION

This dissertation is submitted to the Structural Department, Faculty of Engineering, Ain Shams University, for the degree of Master of Science in Structural Engineering.

The work included in this dissertation was carried out by the author in the Structural Department, Faculty of Engineering, Ain Shams University from January 2013 to March 2017.

No part of this dissertation has been submitted to any other university or institute for the award of a degree or a qualification.

**Author's Name:** Mahmoud Adel Belal

**Signature:**

**Date:**

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| | |
|---|---|
| $BC$ | Total bonus cost |
| $BC_f$ | Fixed bonus cost |
| $BC_v$ | Variable bonus cost |
| bj | Goals specified for function$f_j(\boldsymbol{x})$ |
| BOP | Bi-criteria optimization problem |
| BT | Certain time that BC take place before reaching it. |
| $C_{cmaxi}$ | The maximum crashed cost for activity i |
| $C_{ni}$ | Normal direct cost for activity i |
| $C_i$ | Direct cost for activity i without crashing |
| CPM | Critical path method |
| $C_{sli}$ | The linear cost slope for an activity i |
| di | Crashed duration |
| Di | Normal duration |
| $D_{ij}$ | Normal duration for the activity |
| dj | is the deviation from the goal bj for the jth objective |

| | |
|---|---|
| $d_j^-$ | underachievement deviational variables |
| $d_j^+$ | overachievement deviational variables |
| $d_1^+$ | overachievement deviation for time function |
| $d_1^-$ | underachievement deviation for time function |
| $d_2^+$ | overachievement deviation for Cost function |
| $d_2^-$ | underachievement deviation for Cost function |
| FF | Finish to finish activity relationship |
| $f_i$ | Function i in weighting method problem |
| $f_n(\bar{x})$ | General definition for any function |
| FS | Finish to start activity relationship |
| $g_i(\bar{x})$ | First function of the formal definition of MOOPs |
| $h_i(\bar{x})$ | Second function of the formal definition of MOOPs |
| $dindC$ | Daily Indirect Cost |
| $indC$ | Total Indirect Cost |
| $indC_f$ | Fixed Indirect Cost |
| $indC_v$ | Variable Indirect Cost |

| | |
|---|---|
| $L_1$ | The lower bounds for the objective function $f_1(\boldsymbol{x})$ in bounded objective function |
| $L_2$ | The lower bounds for the objective function $f_2(\boldsymbol{x})$ in bounded objective function |
| m | Number of inequality constraints for the first function of the formal definition of MOOPs |
| Min Z | Function to be minimized |
| MOOPs | Multi-objective optimization problems |
| P | Number of inequality constraints for the second function of the formal definition of MOOPs |
| $PC$ | Total penalty cost |
| $PC_f$ | Fixed penalty cost |
| $PC_v$ | Variable penalty cost |
| PT | Certain time that PC take place after reaching it. |
| P(w) | Weighting method problem |
| P(ε) | ε-constraint method problem |
| P(ε-w) | Hybrid method between ε-constraint and weighting methods |
| P(Bε-w) | Bi objective hybrid method between ε-constraint and weighting methods |
| P(GP) | Goal programming method problem |
| P(FP) | Fuzzy programming method |
| SF | Start to finish activity relationship |

| | |
|---|---|
| SS | Start to start activity relationship |
| TCT | Time-cost trade-off analysis |
| $T_{cmaxi}$ | The maximum crashed time for activity i |
| $T_{fn}$ | Finish time of the project |
| $\boldsymbol{T_{sci}}$ | Number of crashed days |
| $T_{s1}$ | Start time of the project |
| $T_{si}$ | The start time of activity i (processor) |
| $T_{sj}$ | The start time of activity j (successor) |
| $T_{fi}$ | The finish time of activity i (processor) |
| $T_{fj}$ | The finish time of activity j (successor) |
| $U_2$ | The upper bounds for the objective function $f_2(\boldsymbol{x})$ in bounded objective function |
| $w_i$ | weighting factor for the objective function i |
| $\boldsymbol{x_0}$ | Start time for the project |
| $\boldsymbol{x_i}$ | Start time for activity x |
| $\boldsymbol{x_j}$ | Finish time for activity x |
| $x_n$ | The project duration |