# Laborer-Subcontracting Practices 

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#### Abstract

Despite the rapid development in the construction industry and the introduction of new technologies, many projects still fail to meet target deadlines. Shortage in manpower and skilled laborers can be one of the reasons for delays. In markets with high economic growth and economic expansion such as the U.A.E (United Arab Emirates) and Dubai, the shortages in labor are more pronounced. Laborer-subcontracting practices are used sometimes to increase production rates and meet project deadlines. This paper describes and analyses the laborer-subcontracting practices currently being used and in particular attempts at defining a maximum overtime rate for laborers in the laborer-subcontracting method to ensure that the contractor gains both the time saved during overtime but and also reduces the cost per unit produced. The mathematical model formalizes a closed-form equation for overtime pay in similar situations and as such is applicable worldwide. Validation of the model and formula has been tested successfully by analyzing historic data.


Keywords: Productivity Improvement, Scheduling, Construction Project Management, Wages, Labor Relations

## Introduction

Several studies suggest that the labor productivity in construction has decreased in comparison to other industries especially in the last four decades in U.S.A. In contrary, the average hourly wage per man-hour work has increased. These figures show that construction industry seriously lags other industries in controlling, developing and applying labor saving ideas. Furthermore, despite the rapid development within the construction industry and the high competencies many projects still fail to meet target deadlines. Shortage in manpower and skilled laborers is one of the main reasons for that. In the Middle East, particularly the U.A.E (United Arab Emirates); the situation might be worse with no previous studies and data. In 2006, Statistics show the UAE as the region's top spender on construction projects with $\$ 294$ billion worth of building work announced and being constructed - more than Bahrain, Qatar and Oman combined (Ditcham, 2006). Despite this rapid development within the construction industry and the high competencies many projects have failed in providing clients with a high service quality, on time and budget delivery. Shortage in manpower and skilled laborers was one of the main reasons. Lately, more than 300000 of the unauthorized laborers left the UAE, as a result the overall construction cost increased by $20 \%$ and more than $50 \%$ in some trades like masonry work.

Scheduled overtime is the planned overtime extended to complete a certain task, work package, or milestone, before a deadline. Scheduled overtime is the practices extensively in the UAE and other gulf states to offset labor shortages. There seems to be no consensus on the effect of scheduled overtime method in construction industry in the literature. Mayo (Mayo et al 2001 concluded in their study that the overall average productivity increased when labors worked limited scheduled overtime on daily and weekly basis. In contrary, the Construction Industry Institute (CSI 1994), the Mechanical Contractor Association (MCAA 1994), Business Roundtable (BR 1990) and National Electrical Contractor Associations (NECA 1989) all found individual employee productivity declined with overtime hours, particularly after 40 hours of work per week. This lack of consensus can be attributed to the fact that there are several other factors that affect productivity in scheduled overtime. Some of these factors are associated with labors' superintendent and might be classified as managerial factors such as planning and control (Olomolaiye et al 1989), material movement and crew interference and material management (Olomolaiye and Harris 1995). Other factors are non-managerial and mainly related to labor situation, the environmental and site conditions.

It is important to note that the practice of scheduled overtime in the UAE and several other countries around the world is entirely different from the ones studied in the previous literature cited above. In these situations scheduled overtime is more appropriately dubbed "laborer subcontracting" as will be presented in the next section.

This paper presents an analysis of the laborer-subcontracting method and in particular attempts at defining a maximum overtime rate for laborers in the laborer-subcontracting method to ensure that the contractor gains both the time saved during overtime but and also reduces the cost per unit produced. The next section describes the laborer subcontracting method in more detail. This is followed by a mathematical model of the method which formally defines all the variables involved and extracts a closed-from term for the maximum acceptable overtime rate based on the based, paid and actual production rates. Then in the next section, data analysis is applied to demonstrate with a numerical example.

## Laborer-Subcontracting

In order to remain consistent throughout the paper, we will define production rate as the number of output units per unit of time, e.g. 25 tons of steel per day. The productivity on the other hand is defined as the number of output units per man-hour of work, e.g. 5 tons per man-hour.

In order to meet strict deadlines, it may beneficial sometimes to increase the production rates of some activities. By increasing the production rate of repetitive tasks on the project schedule one could decrease the duration of these tasks and hence may impact the overall project duration. The main problem facing construction contractors working the Gulf states and in particular in the UAE, is the lack of laborers. Therefore, increasing the production rate by increasing the resources assigned to these tasks is usually unpractical because of the lack of labor and the labor shortages that happen relatively frequently. Similarly, the amount of overtime work that can be carried out is limited by the hours of the day especially in the summer where the temperature exceeds 120 degrees frequently. On the other hand increasing the productivity of the laborers itself would result in a shorter duration and may even result in cost savings as will be discussed below.

Table 1: Labors production rates for fixing steel reinforcement (Ref. AMANA [12]).

| S.No. | Description | Manpower | Equipment | Unit | Output |
| :---: | :---: | :---: | :---: | :---: | :---: |
| a. | Reinf. of Footing | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 300 |
| b. | Reinf.of Stub Column | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 200 |
| c. | Reinf. of Strap Beam | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 200 |
| d. | Reinf. of Tie Beam | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 200 |
| e. | Reinf. of Wall | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 300 |
| f. | Reinf. of Column | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 300 |
| g. | Reinf. of Beam | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 300 |
| h. | Reinf. of Solid Slab | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 200 |
| 1. | Reinf. of Lintel | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 150 |
| j. | Reinf. Copying beam $20 \times 20 \mathrm{~cm}$ | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 150 |
| k. | Reinf. of Parapet | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 200 |
| 1. | Reinf. of Arch Lintel | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 150 |
| m. | Reinf. of Staircase | $1 \mathrm{SF}+1 \mathrm{H}$ |  | KG / Day | 250 |
| n. | Mesh Reinforcement | $1 \mathrm{SF}+2 \mathrm{H}$ |  | M2 / Day | 250 |

In the Gulf States, and indeed in the UAE, construction industry runs six days a week. Labors have to work eight hours per day and any work beyond these hours will be considered as overtime. Laborers are expected to meet set production rates. The basic production rates of each trade will vary depending on the trade itself, company's profile and labor experience. Each company has its own base production rates. For example, Table 1 shows expected production rates for fixing steel reinforcement for a large contractor in the UAE [12].

These production rates are conservative and are usually easily achievable by the laborers. Due to the low wages in construction industry, most companies will let their labors work for more than eight hours a day assuring that the minimum planned - prescheduled - productivity is achieved. Most likely, engineers won't plan the overtime hours unless their projects are behind the planned schedule. In this case, the overtime hours will be offered to the laborers on a lump sum basis. In other words, laborers are offered a lump sump amount (which translates to extra hours by dividing it by the hourly rate) given that the laborers (as a crew) meet a specific deadline. The lump sum scheduled overtime might be given on a daily or weekly basis depending on the task, the number of labors assigned to do it and the person who is in charge of labors productivity such as engineers, engineer assistants or foremen.


CASE A planned cost = actual cost (using apparent maximum rate)

Figure 1: The relationship between the original (base), paid and actual production rates

The lump sum scheduled overtime hours will almost all the time result in a significant increase in laborers' productivity. The increase in labor productivity usually happen because of two main facts; the first one is that base production rates are usually very conservative (and often under estimated); secondly the main goal of the labors when working overtime using this method it to meet the set amount of work to be done (output units of work) and this will allow labors to stop the work once they have achieved their assigned work quotas regardless of the time they actually takes. Therefore, as soon as labors finish their task they are free to leave and the overtime hours which have been assigned to them on a lump sum basis will paid. This fact creates an interesting situation, where the paid hourly rate is lower than the actual effective hourly rate as will be described next.

## Mathematical Model for Laborer-subcontracting

The relationship between the original (base), paid and actual production rates is shown in figure 1. The base production rate is based on the original base case such as those shown in Table 1 which is based on a conservative estimate of labor productivity, while the actual production rates are the ones actually achieved with the increased labor productivity. The paid production rate is the equivalent rate on which the lump sum amount is determined. The initial assumption of the labor subcontracting method is that the base productivity is lower than the paid productivity. Furthermore the actual productivity achieved by the laborers is higher than the one they are paid based on, i.e., $P_{b} \leq P_{p} \leq P_{a}$. In the discussion of the next section the following notation s are used:
$C_{o}=$ cost per man hour for overtime
$C_{b}=$ cost per man hour for base-case
$U C_{o}=$ cost per unit overtime
$U C_{b}=$ cost per unit for base-case
$P_{b}=$ base productivity
$P_{a}=$ actual productivity
$P_{p}=$ paid productivity
$U=$ Units
$H_{b}=$ hours taken to produce $U$ units using the base productivity
$H_{a}=$ hours taken to produce $U$ units using the actual productivity
$H_{p}=$ hours taken to produce $U$ units using the paid productivity
The idea is to compare the cost per unit in the base case and compare it with cost per unit in the overtime case. The cost per unit in the base case can be given by dividing the total cost for producing the units by the number of units $(U)$. The total cost for producing the U units is in turn equal to the number of hours it takes to produce the $U$ units, $H_{b}$, times the cost per man-hour. Therefore the cost per unit in the base case is,

$$
\begin{equation*}
U C_{b}=\frac{C_{b} \times H_{b}}{U} \tag{1}
\end{equation*}
$$

Also given the base productivity, $P_{b}$, one can determine the number of hours it should take to produce these, $U$ units, $P_{b}=\frac{U}{H_{b}} \therefore H_{b}=\frac{U}{P_{b}}$
Substituting in (1), we get cost per unit in the base in terms of the base productivity as,
$U C_{b}=\frac{C_{b} \times\left(\frac{U}{P_{b}}\right)}{U}$
$=\frac{C_{b}}{P_{b}}$
Now one needs to determine the cost per unit in the overtime case to compare with that of equation 4 . The unit cost in the overtime case can be given by,
$U C_{o}=\frac{C_{o} \times H_{p}}{U}$

In the overtime case however, it is important to note that the labors are paid based on an assumed productivity $\left(P_{p}\right)$ that is in fact usually lower than their actual productivity ( $P_{a} \leq P_{b}$ ). In that case it is easy to see that the cost per man-hour in the overtime case, $C_{o}$, will therefore be higher than the cost per man-hour in the base case, $C_{o} \geq C_{b}$. To determine the cost per man-hour in the overtime case, $C_{o}$, the total cost of producing the $U$ units using overtime is divided by the actual hours worked. The total cost of producing the $U$ units using overtime can in turn be calculated by multiplying the cost per man-hour (which is the same as in the base case) by the hours taken to produce $U$ units assuming the paid productivity $H_{p}$, i.e. the productivity that the laborers are paid based on if they work overtime, $\left(P_{p}\right)$. Therefore the cost per man-hour in the overtime case is given by,

$$
\begin{equation*}
C_{o}=\frac{H_{p} \times C_{b}}{H_{a}} \tag{5}
\end{equation*}
$$

Therefore one can see that the cost per man-hour in the overtime case, $C_{o}$, will therefore be higher than the cost per man-hour in the base case since the laborers will finish the same $U$ units in $H_{a}$ hours, which is less than the $H_{p}$ hours they are paid for (because $P_{a} \geq P_{b}$ ). Also, since $P_{p}=U / H_{p}$ and $P_{a}=U / H_{a}$ equation 5 can be also written as,

$$
\begin{equation*}
C_{o}=\frac{P_{a} \times C_{b}}{P_{p}} \tag{6}
\end{equation*}
$$

Substituting equation 6 in 4 we get,
$U C_{o}=\frac{\left(\frac{P_{a} \times C_{b}}{P_{p}}\right) \times H_{p}}{U}$
From equation 6, we can state that the ratio of the base hourly cost to the overtime hourly cost is the same as the ratio between the actual productivity and the paid productivity,
$\frac{C_{o}}{C_{b}}=\frac{P_{a}}{P_{p}}$
This points out to an interesting paradox. As the actual productivity increases in relation to the paid productivity, the time it takes to produce the same $U$ units will decrease and therefore the cost per man-hour will increase. However that is not the entire picture since the determining of whether to use overtime in that case is the cost per unit, $U C_{o}$ and $U C_{b}$, rather than the hourly cost. What is needed now is to determine the relationship between the three kinds of productivity involved; the base productivity, paid productivity, and the actual productivity. In other words, what is the minimum paid productivity such that the contractor will save time and money.

$$
\begin{equation*}
U C_{o}=\frac{\left(\frac{P_{a} \times C_{b}}{P_{p}}\right) \times H_{p}}{U}=\frac{\left(\frac{P_{a} \times C_{b}}{P_{p}}\right) \times \frac{U}{P_{p}}}{U}=\frac{P_{a} \times C_{b}}{\mathbf{P}_{p}^{2}} \tag{8}
\end{equation*}
$$

Since one of the initial assumptions of the laborer subcontracting method is that the actual productivity is higher than the base productivity, it is clear that the contractor is going to save time by working overtime. However in order for the contractor to save money as well the cost per unit while working overtime has to be lower than the cost per unit in the base case, i.e.

$$
\begin{equation*}
U C_{b} \geq U C_{o} \tag{9}
\end{equation*}
$$

Substituting equations 3 and 8 into equation 9 above we get that,

$$
\begin{equation*}
\frac{C_{b}}{P_{b}} \geq \frac{P_{a} \times C_{b}}{P_{p}^{2}} \tag{10}
\end{equation*}
$$

i.e.,

$$
\begin{equation*}
P_{b} \leq \frac{\boldsymbol{\rho}_{p}^{2}}{P_{a}} \tag{10}
\end{equation*}
$$

or,

$$
\begin{equation*}
P_{p} \geq \sqrt{P_{a} \times P_{b}} \tag{11}
\end{equation*}
$$

In the case where the laborers' actual productivity is equal to one they are paid based on (i.e. $P_{a}=P_{p}$ ), then equation (10) reduced to $P_{b} \leq P_{p}$. This simply states that if the actual productivity of the laborers (which is the same as the one they are paid based on) is higher than the base productivity then the contractor will save time and money over the base productivity case. Similarly is the actual productivity Pa is know and is set as the paid productivity $\mathrm{Pp}=\mathrm{Pa}$ then equation 11 reduces to $\mathrm{Pa}<=\mathrm{Pb}$. The various possible cases are shown in Figure 2. The 4 cases show different relationships where the contractor can save money, time or a combination of both depending on how much is offered in lump sum. The important feature here is that the upper limit on the lump sum amount offered to the labors depends on both the base productivity and their actual productivity, which can only be determined by analyzing historic data as shown in the next section.

## Data Collection and Analysis

In order to effectively utilize equation 11, we need to define a relationship between the actual productivity and the paid productivity, since the base productivity is usually set by the company a-priori. Therefore, historic data from company records from two major contractors who regularly practice laborer subcontracting in the UAE was analyzed (AMANA and TWAM). Historic data were collected from these companies and data was normalized as a percentage of the base productivities to uniformly assess the effect of paid productivity on actual productivity. Although this relationship is different for different tasks, the general trend found in the data is shown in Figure 3, which the relationship for a small sample of the data analyzed for the task of fixing steel reinforcement. As the paid productivity increases the actual productivity increases linearly until a certain critical point, where the labors have reached their physical limit and are no longer able to increase their productivity further. Beyond this critical point the amount of work to be carried out becomes a factor. When amount of work scheduled in overtime is extensive, the labors are required to work for extended amount of times and their actual productivity starts to dip. However, for relatively short durations of overtime, the labors are able to maintain their maximum productivity. Therefore there is another critical value and this is the critical quantity of work to be carried out during overtime beyond which the productivity of the labors starts to dip. This critical quantity depends on the nature of each task. However, since the data analyzed has shown that the amount of critical work scheduled overtime rarely exceeds the critical quantity of work, the initial critical value of paid productivity usually governs the maximum lump sum amount to be paid and equation 11 can be rewritten as,

$$
\begin{equation*}
P_{p} \geq \sqrt{m \times P_{p} \times P_{b}}, P_{p}<c \text { or simple } P_{p} \geq m \times P_{b}, P_{p}<c \tag{12}
\end{equation*}
$$

Were $m$ and $c$ are constants that depends on the type of task to be carried out.


CASE A planned cost = actual cost (using apparent maximum rate)


CASE C planned cost a actual lost (using apparent maximum rate), i.e. you paid the laborers an hourly rate more than apparent maximum but still ended up saving time and money


CASE D planned cost < actual cost (using apparent maximum rate), i.e. you paid the laborers an hourly rate more than apparent maximum but higher than case $C$ so that you ended up saving time only and

NOT money

Figure 2: The possible cases for base, paid and actual productivities

## Conclusions and Recommendations

This paper presented a model for the laborer subcontracting method, which is widely practiced in many countries to meet schedule deadlines. The method is involves paying labors a lump sum amount to meet a compressed schedule by working overtime hours. The practice was analyzed and closed form equations were derived to limit the amount of lump sum values offered to the labors to ensure that the contractor can save both time and money. It is important to note that this practice is based on a set of assumptions which may not be valid in all cases. The most important assumption is that the initial productivities, based on which the labors get paid, are conservatively set. This in effect makes this method applicable when the labors are paid daily rates and required to meet certain production quotes. Other aspects of the practice such ethical, managerial and socio-political aspects are not discussed and deserve more attention in future research.


Figure 3: Paid versus actual productivity

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