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Worker Crew Planning as an Important Aspect of Improving Construction Productivity

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Abstract:

Workforce is the fundamental and critical concern in success or failure in a construction project; however conventional construction practices have underutilized this important resource. This fact is proved by observing productivity values of construction industry lagging behind the other industries over the years. Therefore it may very well be the right time for a paradigm shift from conventional work force management practices to innovative, creative and more technically sound best practices. Based on McGrath (1964), Gladsetin's (1984) and Hackman (1987) Input-Process-Ouput models, this paper is focusing on developing a comprehensive workforce management framework which provides a holistic understanding of the relationship between tasks and people. Here the aim is to improve productivity by eliminating waste and non-value adding activities by redesigning the work flow. Furthermore this paper tries to present a methodology for systematic identification, evaluation, and recognition of productivity improvement opportunities.

Key Words: Labor productivity, construction productivity, worker performance, pre-construction planning, I-P-O models, workforce management

1. Introduction

Over the last decade North American and specially Canadian construction industry is having a hard time in meeting their labour demands and retaining their skilled workers. It is predicted that this trend will continue in the future as well (Statistics Canada 2012, Construction Sector Council 2011). On the other hand construction labor costs per dollar of investment continue to increase gradually (Productivity Alberta, 2013). Literature highlighted that labour cost accounts for 33–50% of the total construction costs (Hanna et al, 2001). Therefore labour is an important resource in any construction project in any nation. However productivity in Canadian construction projects has been lagging behind the other industries during last decades (Statistics Canada 2012). According to Merrow et al. (2009) inherent labour intensive nature is one of the main factors affecting the overall construction productivity. Hence that highlights the failure of current labour practices to optimize the labour as an important resource. Therefore there is a strong need to find innovative methods to improve the worker productivity and performance levels. Merrrow et al (2009) in his report highlighted that better planning, controlling in processes and high supervision on labourers are some key indicators on achieving higher labour productivity in construction projects. Therefore one significant area to pay attention is planning and better managing of the worker crews starting from pre-construction stage to project closeout.

However conventional construction practice does not give sufficient attention to worker crew planning at the pre-construction stage. This deficiency in macro planning can have considerable adverse effects at the micro level execution of the tasks. This can be improved by giving special attention to worker crew planning in particular creating structured worker groups, worker utilization and assignment of suitable supervisors. This paper describes the initial steps in developing a comprehensive framework to create high performing structured construction teams.

2. Why we need structured groups?

Just like in any other industry groups are the basic building blocks for construction projects as well. Therefore people are a fundamental and critical concern in success or failure of any project. While groups can yield benefits, if not properly structured they also can adversely affect the project outcomes. According to Hackman (1987) poorly managed teams:

"*waste the time and energy of members, rather than use them well; they can enforce norms of low rather than high productivity; they sometimes make notoriously bad decisions. Patterns of destructive conflict can arise, both within and between groups. And groups can exploit, stress, and frustrate their members*".

High performing highly cohesive teams do not happen in accident. It needs careful selection of team members, high level of training, leadership, reengineering the process, continuous practice of elimination of waste and process improvements. Such teams have little room for trial and error. Following are some good examples for achieving high effectiveness by incorporating the above mentioned best practices. They are, world famous motor racing team "Ferrari" changing tires at pit stop less than one minute, physicians and supporting medical teams who have zero tolerance in their operations, baton change of US 100m Olympic relay team. Therefore it is important to identify the factors that support creating such teams and how they can be adopted in the construction industry.

2.1 Team and team work

In team work literature frequently team is defined as "two or more individuals with specified roles interacting adaptively, interdependently, and dynamically toward a common and valued goal" (Dyer, 1984; Salas et al., 1992). While teamwork is defined as "a set of interrelated thoughts, actions, and feelings of each team member that are needed to function as a team and that combine to facilitate coordinated adaptive performance and task objectives resulting in value-added outcomes" (Morgan et al. 1986; Salas et al. 2004).

Macgregor's theory X assumptions states that in order to manage the workers there should be a strict discipline and order with close monitoring and management (Gareth and Jennifer 2011). The above explanation is proved by observations in the construction industry where worker groups (teams) are managed using hard and fast rules. However based on the definition of teams; effective teams require more than just a set of tasks and rules. One important point that can be derived from existing research is that effective teams require interaction with each other coordinate, cooperate and share their knowledge, skills and experiences to achieve goals and objectives (Salas 2005). This essentially leads to the above definition of team work. This explains the fact that teams and team work should be considered together rather than in isolation.

In all areas of a construction project multiple individuals from multiple trades and organisational tiers have to work towards a common goal. In addition interdependence of multiple level of hierarchy is also an inherent characteristic. Therefore there should be a highly cohesive team and high level of team work to achieve set project goals. Hence it is important to have a paradigm shift of current worker management practices to understand relationships of team and teamwork holistically for the purpose of redesigning the work process to increase efficiency and productivity.

Fundamentally there are two levels in groups; individual level and group level. Individuals' thoughts, actions, and emotions are shaped by individual level processes, but that each individual is also shaped by the group which he or she belongs (Hackman 2002). This fact can be better described by Kurt Levin's theory where he identified, behavior of group members as a function of member's personal characteristics and their interaction with the environmental factors of the group. Furthermore he mentioned that the groups are more than the sum of its parts. Thus team performance cannot be reliably predicted from team personality composition and task characteristics alone, but also depends on the interactive effects of team behaviour characteristics. Therefore when planning groups one cannot consider individual level or group level in isolation. To better illustrate individual level and group level dimensions and their interaction process; Input-Process-Output (IPO) models provide a framework to visualize them and to understand how they influence on team outcomes.

3. I-P-O model as a guidance to understand worker crew planning

In team performance literature, Input-process-output model (IPO model) mainly based on the McGrath's team behaviour model. His motivation of developing that model is to analyse how the group outcome depend on the structure of the input factors and its interaction process. In McGrath‟s IPO model (figure 1) input refers to the group input factors such as size, mix (group composition) and it is govern by the mixture of individual characteristics. Processes are regarded as the interaction of individuals in both task and social levels. Therefore, in the model, processes act like an interface between input factors and outputs. And out puts are the performance of the group memebers, satisfaction of members and level of group integration (Hackman, 1987, Kozlowski and Ilgen, 2006).

Hackman (1987) later illustrated McGrath's model in a more comprehensible way. In Hackman (1987) framework, he classified both input and output variables into three sets: individual group members, the group as a whole, and the environment in which the group operates. To trace changes in the state of the system over a specified time period he introduced a time line. Therefore changes in all relevant variables can be assessed at any two points in time (input in t_1 and output in t_2).

4. Research frame work for creating structured construction teams

Based on McGrath's and Hackman's I-P-O models, a research frame work has been developed to improve group effectiveness in construction by creating structured construction teams. Basic structure of the research model can be illustrated in following way (Figure1).

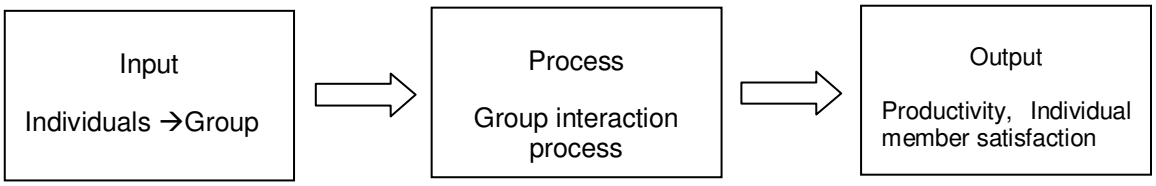

Figure 1: I-P-O framework

One key assumption is that group interaction process is governed by the structure of input factors. This assumption is supported by the definition given for processes in social science. It defines process as "group behaviors that can be observed, are influenced by different input factors and affect the outcome" (Brodbeck, 1996).

Hence in this framework input state affects group outputs via the interaction that takes place among members (Figure 1). Hypothetically we can assume that high cohesiveness that results from structured input factors can cause a certain group to perform better. Therefore it should be possible to explain the performance difference by comparing the structure of the groups. Thus this sequence provides us a guideline to compare and contrast performances of groups and rectify them by adjusting the structure of the inputs.

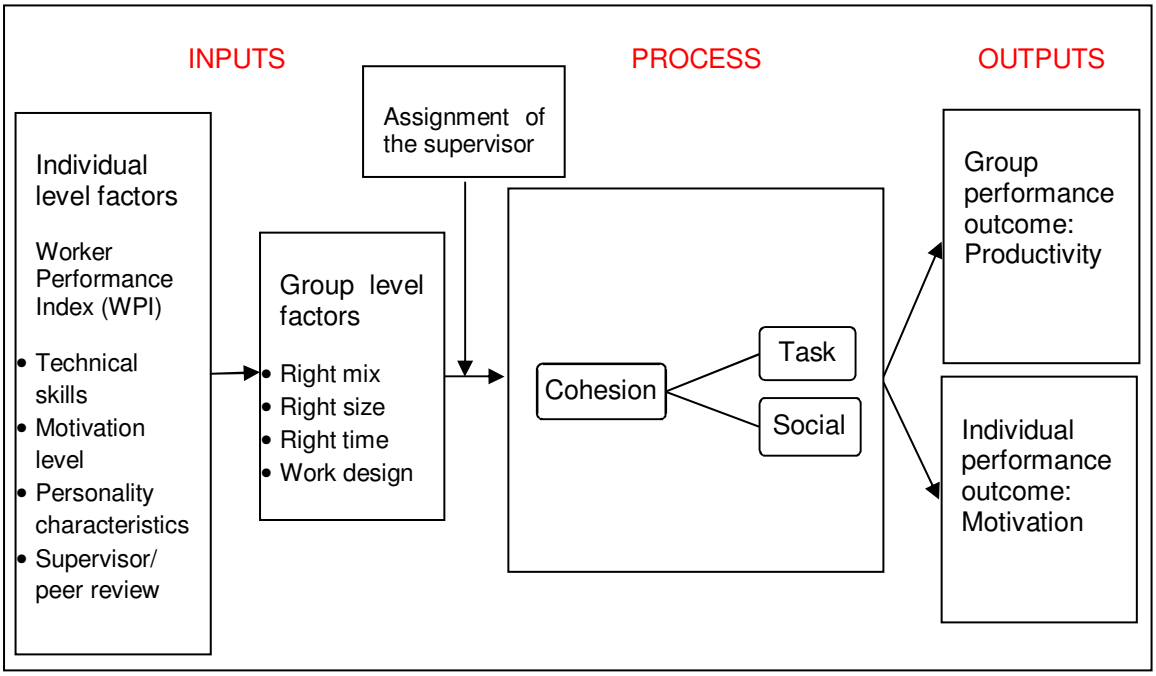

Figure 2: Research frame work on worker crew planning

One of main intentions of the developed framework (Figure 2) is to structure input factors in such a way that will favorably influence group interaction process to enhance the group performance. Like most of I-P-O models this frame work consists of three main parts; input, process and outputs. To set up inputs correctly in the individual level, this paper is proposing to use the Worker Performance Index (WPI) developed by Siriwardana and Ruwanpura (2012). Same worker evaluation methodology can be effectively applied to formulate structured worker groups with predictable outcomes. As shown in Figure 2 between inputs and process, assigning a supervisor has been added. It considered as a separate entity from the inputs and group process. For the process we have considered cohesion as the main criteria. Cohesion is measured using the framework provided by Widmeyer et al. (1985) and Mulen and Cooper (1964). For the outputs we have considered productivity and motivation. Here we consider productivity as a measure of group performance and motivation of workers as a measure of individual performance.

4.1.1 Individual level factors

When defining the individual level factors of the members it is hard to presume how a given individual will behave in a given environment. It depends on personal traits, culture, environmental factors and conditions. Therefore this paper considers individual level factors as a combination of pattern of members' technical skills, cognitive skills, attitudes and personality characteristics. Thus this research model integrates WPI measurement structure to evaluate the individual level factors.

Worker Performance Index (WPI)

Conventionally worker is categorised either skilled or unskilled by only considering the skill levels and experience of the worker. However there may be certain workers who are highly skilled but not motivated enough to perform the tasks and on the other hand there can be workers who are unskilled yet highly motivated to work. Therefore those workers may not perform exactly the same way as expected. This incompatibility can be minimized by using Worker Performance Index (WPI) values. Main objective of developing a worker performance measurement tool- WPI is to improve the worker productivity by analysing their current level of performance. WPI as a common evaluation method will help construction management team (CMT) to rank and evaluate all of their workers in a fair and equal way. This will provide a basis to develop cohesive construction teams based on their performance levels and expected supervisory requirements (Siriwardana and Ruwanpura 2012). WPI is calculated by considering following aspects (Table 1) of a construction worker.

Table 1: WPI evaluation format

Assessment	Description	Weight
Skill level factors (TS)	Evaluates the skill level and experience of the worker.	0.6
Motivation level factors (MO)	Evaluates the motivation level based on Vroom's 1964 motivation theory.	0.2
Supervisor and/or peer factors (Sup)	This is an assessment of worker's immediate supervisor (or peers) based on different aspects of the worker. Personality, Attitude and morale, aggressiveness, leadership potential etc.	0.1
Management factors (Mgmt)	This evaluates the worker records related to management procedures (i.e. attendance, safety records etc.) which are general to all of the workers.	0.1

As indicated in table one, to calculate WPI construction worker undergo four assessments. These assessments are carefully planned to cover all aspects of workers. Each assessment has been developed based on several sub factors. Sum of the scores of these sub factors then added to calculate the factor score (FS) for each assessment and therefore all together WPI is calculated from following formula (equation 1).

$$[1]\ WPI = 0.6*FS_{TS} + 0.2*FS_{Mo} + 0.1*FS_{Sup} + 0.1*FS_{Mgmt}$$

Knowing the WPI of a certain worker will help the CMT to predict the performance of the worker before handing him a responsibility at the site. Furthermore these measurements will help to understand the cross section of the workers based on their current skills, personal traits and motivational levels. This will also help the construction planners to get an informed judgment about their workforce. Moreover this assessment is providing the future supervisors or foremen the pre-knowledge to take an informed judgment about his workforce before executing tasks at site. As evaluation format of WPI is capable of acquiring data based on multitude of indicators of worker performance. Therefore WPI can used to perform an in depth analysis and to compare and contrast different categories of workers.

4.1.2 Group level:

This paper evaluates structured construction crew in different aspects; team composition, structure and work design. Here we have used Sundstrom (2000) and COAA workforce development committee classification (2013) of worker crew planning and explanations to identify the factors which can affect worker group process. They are right mix, right numbers, at the right time and work task design.

Right mix: Conventionally when planning a team people make sure that the team members fulfill required technical aspects to finish a certain task. However they tend to less care about the other aspects, such as cognitive skills, adaptability, cohesiveness, cultural aspects, attitudes and personality of the group members (Hackman 2002). This situation often occurs with the common belief of the diversity within a group may increase the uncertainty, complexity, and inherent confusion in group processes. And the perception of homogeneity promotes the socially cohesiveness within the group (Hackman 2002). Therefore in order to keep the harmonious relations which they believe as a facilitator of team performance, many tend to create groups with the members who are comfortable with each other. However on contrast many research shows that diverse groups tend to generate more and better ideas, innovation and creativity (Hackman 2002, Salas 2005). Current cross section of construction workers represents diverse mix of races, socio-economic groups and cultures. Very often English is not their first language for an increasing number of workers. Moreover, hard to influence 'macho-cultures' can still be found (UK safety guide). Culture plays a dominant role in determining personal behaviors (Hofstede et al. 2005). Therefore planners have to pay great attention to consider these facts when planning construction groups. A well composed team strikes a balance between heterogeneity and homogeneity which has the "right mix" of personalities, behavioural styles and technical skills. One best practice is to letting them work with each other before assigning them in the real task (Hackman 2002). WPI illustrated above can effectively be used in determining the right mix of the construction workers.

Right numbers: The size of a team influences its nature in many ways (Levine and Moreland, 1998). Frequently team builders want to create lager groups as they want to ensure that the team has adequate resources or to establish representation on the team of every function (Hackman 2002). However Levine and Moreland (1998) mentioned that "Overstaffing is riskier than understaffing" because when the team size is big there can be miscommunications, negligence of shared responsibility and the accountability.

Several studies have been conducted to evaluate the relationship between group size and productivity. And they concluded that when the group size increases actual productivity decreases as a result of process losses. Furthermore they have mentioned that smaller groups are better with optimum size of four to six members (Steiner et al. 1972). As a rule of thumb Hackman (2002) identified single digits in team numbers and he recommended group size of six people.

Right time: This paper identifies three elements of right time on structured worker group creation, such as planning the worker strategy early, assigning crew members at appropriate time and realistic worker schedules and shifts. It is recommended to develop project worker strategy early as possible, preferably during the Front-End Planning Phase. With respect to assigning crew member at appropriate time it is recommended to minimize shifting workers from one crew to another arbitrary and when doing it, to consider the current dynamics of the project. For example, adding more and more workers when the project is delayed. This may adversely affect the team cohesion and motivation. Also newly added members may find difficult to blend in to the former members. According to Brooke's law "adding more people to late project make it later" (Hackman 2002). It is recommended to assign worker crews with realistic and favorable worker schedules, working hours and working shifts. Several literatures identifies that worker productivity is lost when workers working in long working hours and with use of extended overtime (CURT 2005)

Task work design: This section tries to classify the tasks based on its characteristics. Similar to Gladsetin's (1984) classification of work design this paper identifies three factors under group task characteristics; namely task complexity, task interdependence and environmental uncertainty. Depending on them structure of worker teams varies. For example tasks with high complexity may require workers with necessary skill levels as oppose to task with less complexity. High interpedent task may require highly cohesive groups as oppose to a task with less interdependent. When the crew planners have a thorough understandings of the task deign they can effectively match task characteristics and worker skill level requirement using WPI.

4.1.3 Assignment of the supervisor:

Supervisor plays an important role as an interface between CMT and the workers. Therefore supervisor influences the process between workers and their performance by providing a leadership, technical guidance and motivation support. Furthermore presence of supervisor at construction site can use as a moderator of the Hawthorne effect to increase the productivity. Because supervisors are behaviorally trained to manage subordinates in ways that extract their cooperation and increase their productivity (Gereth and Jennifer 2011). Gannoruwa and Ruwanpura (2008) have created a worker readiness grid (WRG) to match supervisor with worker by evaluating their technical skill and motivation levels. In the grid, they have identified four different worker clusters and four supervisory styles to match each worker group.

4.1.4 **Process**:

With respect to team process, Tuckman (1965) identifies cohesion, conflict, cooperation, communication, etc., as significant group processes. However several researches on group behavior have considered cohesion as the most important variable linking group processes and group outcomes for small group (Cohen and Bailey 1997; Hackman, 1987; Sundstrom et al. 1990; Carron and Brawley 2000). Sundstrom et al. (2000) indicated cohesion is among most studied predictors of performance. There are a large number of factors which affecting group behaviour but, for practical reasons, only limited number of aspects are examining in this paper. Therefore in this framework we selected only cohesion as the key variable in defining the group process and team effectiveness.

In individual level higher cohesion will lead to higher job satisfaction (Cohen and Bailey 1997) and at the group level cohesion is associated with group performance (Mulen and Copper 1994). Cohesion can be broadly divided in to two components namely task cohesion and social cohesion (interpersonal cohesion). Task cohesion explains the dedication of group to the task and social cohesion explains as the interpersonal attraction of the group members. To get a well performing highly cohesive group, both of the aspects play an equally important role. Hence group has to be socially cohesive and at the same time group members has to be cohesive in task commitment and in goal orient nature.

For the measurement of cohesion in this paper we have used the measurement structure proposed originally by Widmeyer et al. (1985). In their model they have assumed that cohesion as a group property and it can be assessed by both group and individual beliefs of members. Moreover they considered cohesion as a multi-dimensional construct. Firstly they identified two main components such as group integration (GI) and individual attractions to the group (ATG). Group integration (GI) reflects the individual's perception about what the group believes about its closeness, similarity, and bonding as a whole. And individual attractions to the group (ATG) reflect the individual's personal motivations to remain in the group, as well as his or her personal feelings about the group. As shown in Figure 3, they further divided the above two components in to task (T) and social (S) dimensions of cohesion. Thus all together Carron and Brawly (2000) considered cohesion as a multi-dimensional construct with both groups' and individual's central belief best represented by Group Integration-Task (GI-T), Group Integration-Social (GI-S), Attractions to the Group-Task (ATG-T), Attractions to the Group-Social (ATG-S) (Figure 3).

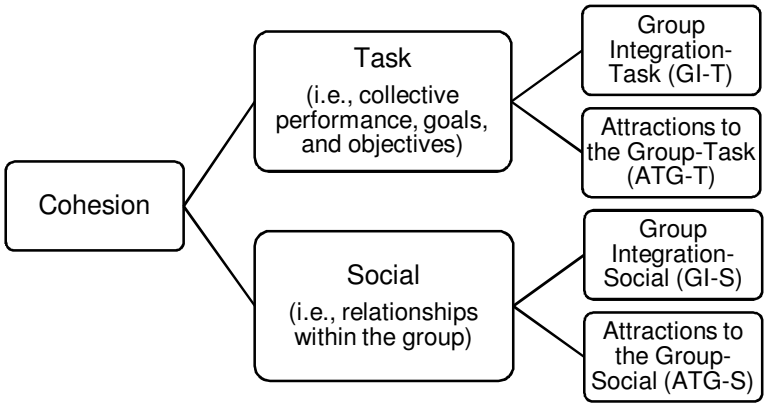

Figure 3: Cohesion evaluation framework

One important point to highlight in their model is that they identified cohesion as a dynamic construct (not a trait), which can change throughout the process of group formation, group development, and group maintenance and group dissolution (Carron and Brawley 2000). Because of the apparent ambiguity in the relation between group cohesion and performance, several studies have attempted to highlight the moderators of cohesion–performance relationships. They identified moderators include group size, group reality, level of analysis, and group interdependence (Sundstrom et al. 2000) member similarities, external competition and threats and group success (Eisenberg 2007). Therefore these identified moderators of cohesion–performance relationships can be positively influenced by structured input factors which described previously.

4.2 Output measurements:

When defining the team effectiveness most common evaluations are productivity, delivery time, quality and number of errors. However there are other aspects not specifically indicated as objectives but defines effectiveness, such as job satisfaction and workability (Hackman and Oldham 1980).

Therefore in this research outputs considered are worker motivation and productivity. Productivity can be considered as an overall measurement of the group performance level and job satisfaction can be considered as a measurement of the individual performance level. Construction labor productivity is a measure of work process efficiency. In a simple way it can be defined as group output relative to input (Sundstrome et al. 2000). Theoretically we can assume that productivity can be increased by optimising labor resources and minimising waste from the work process.

To avoid practical difficulties in data collection on productivity we selected work study measurements (tool time analysis). Use of work study measurements or tool time analysis studies to approximate the worker productivity is a common research tool many researchers have used. Since work studies give a detail analysis of the workers time distribution it identifies areas to improve in order to optimize the worker effectiveness.

To measure the worker satisfaction we measured individual worker's motivation using the method proposed by Hewage et al 2011 which is based on the Vroom's 1964 motivation theory. Here we are making the assumption that worker satisfaction can be approximated by individual motivation.

4.3 Corrective actions to improve performance (feedback)

Based on these measurements CMT can decide on the performance levels of the workers both in individual level (worker motivation output) and in the group level (tool time analysis output). Therefore using this framework depending on the output levels CMT can take corrective actions in to the input factors (figure 2) in three hierarchical levels; individual level, group level and organizational level. For example if the productivity is low then the input factors has to be adjusted accordingly. If worker motivation is low only in few workers then workers has to be shifted to other groups, other tasks or by shifting to another supervisor. If motivation is low in all the members in one group then the change of supervisor or the task can be proposed. If the workers are not motivated to the work as a whole then this issue has to be addressed in the organizational level, by adjusting management strategy, payment and reward structures, working hours or shifts.

Initial best practices: In order to successfully implement this framework in a construction site following best practices were also proposed. Before restructuring the worker crews, it is suggested to calculate Work Performance Indexes (WPIs) of the workers by conducting a careful appraisal of the existing workers and new recruits as an initial step. Here the aim is to evaluate the work force to identify their strengths, weakness before assigning them tasks. To redesign the work processes to eliminate waste (lean construction) and non-value adding activities; conducting a systematic study of relationship between workers and tasks is proposed as the next step. This process can be carried out by several steps based on the principles of scientific management. Conducting a work-study measurement (time-and-motion study) to evaluate the way workers perform their tasks, gather all the informal job knowledge, codifying the new methods. Carefully select workers who possess skills and abilities that match the needs of the task, and train them to perform the task according to the established rules and procedures. These best practices provide a good basis to set up all the input factors into a standard level.

5. Concluding remarks and future steps:

Input Output Process (IPO) frameworks can be used as an effective guideline to better plan the worker crew to improve the productivity of construction activities. This paper tries to describe the studies concerning the applicability of IPO framework in the construction industry and the difficulties involved in its implementation. The guidelines suggested by McGrath (1964) Goldstein (1984) and Hackman (1987) were modified for use in the construction industry. Based on those guidelines and the results of pilot study experiments performed in two construction sites in Calgary following conclusions can be made.

Worker crew planning program to be successful, it should have strong organizational support. CMT, site supervisors and workers should participate in the implementation process. Having a workshop to discuss the program, the methodology for setting the ground rules and the criteria for evaluating performance helps to reduce friction and avoid misunderstandings. Initially it may not be possible to implement this framework to entire site and to the entire work force. Therefore at the initial stage, only a selected worker groups and number of tasks should be selected. This allows more effort and attention to be concentrated on a few tasks and limits the disruption or damage that might occur if a difficulty should arise during implementations. Performance measurement criteria need to be to clearly specify at the outset. Without a clear knowledge of how performance would be measured, setting goals and its comparison with performance is meaningless. With the involvement of unionized labor, the proposed program should be discussed with union officials, and they should be assured that no jobs will be cut and no individual will be punished or rewarded based on his/her performance. Finally it is important to pay a special attention to documentation, data gathering and analysis process because it is crucial to track the progress of the implemented framework.

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