4th Construction Specialty Conference
4e Conférence spécialisée sur la construction

Montréal, Québec
May 29 to June 1, 2013 / *29 mai au 1 juin 2013*

Labour Productivity Improvement through the Use of Best Practices for Infrastructure Construction Projects

H. Nasir[1], C. Haas[1], M. Shahtaheri[1], C. Caldas[2], P. Goodrum[3]
[1] Department of Civil and Environmental Engineering, University of Waterloo, ON, Canada
[2]Civil, Architectural and Environmental Engineering Department, University of Texas at Austin
[3]Department of Civil, Environmental, and Architectural Engineering, University of Colorado at Boulder

Abstract: Infrastructure projects constitute a large portion of the construction industry and are an important part of everyday functioning of a society. Improving labour productivity and project performance are always important for completing projects on time and meeting budgetary requirements. The construction industry has often lagged behind manufacturing industry in terms of labour productivity improvement. One way of improving productivity is the use of best practices. The research presented in this paper focuses on the use of best practices for improving productivity. A best productivity practices implementation index (BPPII) for infrastructure projects has been developed. The index consists of a list of practices that have the potential to improve labour productivity. The planning and implementation level of practices were developed and defined. The development of the index is described in the paper. Labour productivity was measured in terms of productivity factor. Data for infrastructure projects were obtained and regression analysis was performed to see if there is a positive relationship between the use of best practices and productivity. It was confirmed that the higher use of best practices is positively related with improved productivity.

1 Introduction

The construction industry is a major component of a nation's economy and is one of the largest employers of both skilled and unskilled labourers in North America. Infrastructure construction projects accounts for a major portion of the construction industry. The Canada's federal budget for 2010 announced expanding federal investments in infrastructure with $7.7 billion in new infrastructure stimulus funding in addition to the seven-year $33 billion Building Canada plan announced in the Budget 2007 (Canada's Economic Action Plan 2010). The volume of infrastructure construction in United States of America is much higher than Canada. These amounts are in addition to that required for the maintenance and rehabilitation of the existing infrastructure, majority of which has reached its service or design life. In a study undertaken by the Federation of Canadian Municipalities (FCM) in 2007, the infrastructure deficit of municipal governments has been reported as a staggering $123 billion (Mirza 2007). According to the Report Card of the American Society of Civil Engineers (ASCE) on infrastructure of the Unites States of America (USA), $2.2 Trillion are required to bring the country's infrastructure system to acceptable levels (ASCE 2009).

All together, the volume of infrastructure construction will grow and with it the need to improve the construction productivity in order to optimize current and future construction expenditures. Construction productivity affects the outcomes of the national efforts for the renewal of existing infrastructure systems, for building new infrastructure, and to remain competitive in the global market (NRC 2009). While there are certainly opportunities in new innovations to improve construction productivity, innovations are likely to have little impact on productivity, if established processes and practices that are recognized as being necessary to control and improve productivity are not being effectively utilized first. Analysis by Construction Industry Institute's (CII) Research Teams 240 and 252 of CII Benchmarking and Metrics (BM&M) data has clearly shown that productivity typically deviates 25% more or less from the norm on any particular project (CII 2009).

The research presented in this paper lays out a strategy to help improve the productivity of the infrastructure construction sector. The proposal centers on the idea that to improve something, we need to measure it. The proposed research was designed to improve productivity at the project level of the infrastructure construction sector by developing the Best Productivity Practices Implementation Index (BPPII) for infrastructure projects. This paper describes the development and validation process of the index.

2 Background

Labour productivity improvement in the construction industry has gained attention during the last few years. Labour constitutes on average 30 to 40% of the total construction cost (Mohammadian and Waugh 1997).One possible way of improving productivity at a project level is the use of practices that have the potential to positively affect productivity. Different programs have been developed by various organizations at the government and private level to improve performance and productivity in the construction industry. Costa et al. (2006) have provided a review of benchmarking and metrics programs in the United Kingdom, Chile, Brazil, and the United States. Similarly, Nasir et al. (2012) have described the development of a benchmarking and metrics program for performance and productivity improvement in Canada for construction industry. Some of these programs have identified and developed the use of certain practices, which can improve productivity. However, they are mainly developed for improving project performance. Two of these programs developed by the Construction Industry Institute (CII) and Independent Project Analysis (IPA) are discussed below.

The Construction Industry Institute (CII) is a consortium of over one hundred leading owners, engineering and construction contractors, and suppliers. The CII's research has resulted in identifying best practices for sharing and implementation to improve the chances of project success (CII 2006). The Construction Industry Institute (CII) has developed a list of practices known as "Best Practices" which include fourteen (14) practices. Their Best Practices are meant for implementation at different levels such as project, organizational or both. Independent Project Analysis (IPA) is a private international construction benchmarking and metrics corporation headquartered in the US and was founded in 1987. IPA consults on project evaluation and project system benchmarking. This primarily includes large oil companies, chemical producers, pharmaceutical companies, minerals and mining companies, and consumer products manufacturers (IPA 2010). IPA's data and methods are proprietary. The IPA has developed a list of twelve practices, called "Value Improving Practices" (VIPs). The completion of these VIPs is used in evaluating a project's performance. The use of VIPs is considered to have a positive impact on the project performance, increase labour productivity, and reduce rework (Lozon and Jergeas 2008). Table 1 lists practices identified and recommended by CII and IPA.

These practices have a statistically valid positive relationship with project performance measures such as cost and schedule, however not all organizations directly measure this effect using quantitative metrics. These practices also have the potential to increase labour productivity and on-time material delivery which would reduce double handling and rework; however, there is no metric identified to verify these impacts (Lozon and Jergeas 2008). It is stated that adopting CII best practices has a positive effect on project cost and schedule reduction (CII 2003). Best practices can reduce non-productive time or increase the time available for direct work. Best practices can reduce rework; improve schedule, job-site safety, and project quality (NRC 2009; Hwang et al. 2009).

Table 1: List of Practices Identified by CII and IPA (CII 2006, IPA 2010)

Construction Industry Institute		Independent Project Analysis	
1	Pre project planning (PDRI)	1.	Classes of Facility Quality
2	Alignment	2.	Constructability Reviews
3	Constructability	3.	Customized Standards & Specifications
4	Design Effectiveness	4.	Design to Capacity
5	Materials Management	5.	Energy Optimization
6	Planning for Startup	6.	Predictive Maintenance
7	Team Building	7.	Process Reliability Modeling
8	Partnering	8.	Process Simplification
9	Quality Management	9.	Technology Selection
10	Implementation of Products	10.	Traditional Value Engineering
11	Benchmarking and Metrics	11.	Waste Minimization
12	Change Management	12.	3D CAD
13	Disputes prevention & Resolution		
14	Safety: Zero Accident Techniques		

There is a large amount of literature available on factors that influence productivity, but no index of a set of independent and complete best practices for improving it on a project. The development of the Best Productivity Practices Implementation Index (BPPII) Infrastructure builds on the efforts of the CII Construction Productivity Research Program Team 252 (RT-252) that has developed the BPPII Industrial for improving productivity on industrial construction projects. The practices defined in BPPII Infrastructure are different from Best Practices of CII and others, because the BPPII specifically focusses on improving productivity at job site. The BPPII also defines the implementation level of practices and helps in identifying practices with low level of implementation.

3 Research Methodology

The development of the BPPII for the infrastructure sector involved a thorough investigation of the available literature on the improvement of construction productivity. The available literature on the reasons for low productivity and different techniques, practices, and methods for productivity improvements were analyzed and synthesized. After the literature review, several steps were required to develop and validate an infrastructure BPPII. These are: (1) identify best productivity practices for the infrastructure sector. Structured process was used to derive, categorize and produce an ontology of best practices for infrastructure construction; (2) synthesized the initial input into a formalized set of BPPII's categories, sections, and elements; (3) assigned weights to each of the individual elements, sections, and categories that are part of the BPPII based on their relative importance in influencing labour productivity; (4) validated index in the field by obtaining data on projects' scores on the BPPII and the projects' productivity performance; and (5) analyzed data to observe relationship between best practices and productivity. Extensive collaborations with industry were required to complete these processes.

4 Best Productivity Practices Implementation Index (BPPII) - Infrastructure

The Best Productivity Practices Implementation Index (BPPII) is an index based on a set of practices that have the potential to improve productivity at the project level for infrastructure construction projects. In total, there are 61 practices identified and organized into 61 elements, 20 sections, and six categories. The categories: (1) Materials Management; (2) Construction Machinery and Equipment Logistics; (3) Execution Approach; (4) Human Resources Management; (5) Construction Methods; and (6) Health and Safety. Each of the categories is further divided into sections, and each section is divided into elements. Table 2, shows the complete list of elements, sections, and categories of the Infrastructure BPPII. The elements represent specific practices that are known to have a positive effect on labour productivity. They have been identified through literature review and expert opinions, and have been anecdotally proven to positively affect productivity (Rojas and Aramvareekul 2003; Kazaz and Ulubeyli 2007; Lozon and Jergeas 2008; Dai et al. 2009; Tabassi et al. 2012). The sections and their elements are organized into individual audit forms or score sheets. Each element or practice is scored by filling the audit form or assessment score sheet which is explained below.

Table 2: BPPII Infrastructure Categories, Sections and Elements

I - **MATERIALS MANAGEMENT**
A. Procurement Strategy
- A1. Procurement Procedures & Plans for Materials & Equipment
- A2. Long-Lead/Critical Equipment & Materials Identification
- A3. Procurement Team

B. Materials Management Systems
- B1. Project Team Materials Status Database
- B2. On-Site Material Tracking Technology
- B3. Materials Delivery Schedule

C. Receipt and Inspection of Materials
- C1. Materials Inspection Process
- C2. Materials Inspection Team
- C3. Post Receipt Preservation & Maintenance

II – CONSTRUCTION MACHINERY & EQUIPMENT LOGISTICS
A. Construction Machinery & Equipment Availability
- A1. Procurement Procedures & Plans for Construction Machinery
- A2. Construction Machinery Productivity Analyses
- A3. Construction Machinery and Equipment Maintenance

B. Tools and Equipment Management Best Practices
- B1. Site Tools and Equipment Management Strategy
- B2. Tools & Equipment Tracking
- B3. On-site Tools Maintenance
- B4. Construction Machinery & Equipment Utility Requirements

III – EXECUTION APPROACH
A. Planning
- A1. Short Interval Planning
- A2. Well defined scope of work
- A3.Use of Software
- A4.Dedicated Planner
- A5.Construction Work Packages (CWP)

B. Constructability Reviews
- B1. Design readiness for construction
- B2. Utility Alignment & Adjustments
- B3. Contract Types/Strategies
- B4. Model Requirements/3D Visualization

C. Acquisition Strategy
- C1. Right of Way, Land, and Utilities Acquisition Strategy
- C2. Contracts & Agreements with Agencies
- C3. Utility Agreements

D. Regulatory Requirements/Reviews
- D1. Environmental Requirements
- D2. Regulatory Requirements/Permitting Requirements

IV - HUMAN RESOURCES MANAGEMENT
A. Planning
- A1.Crews Composition/Crew Formation
- A2. Skills Assessment and Evaluation

B. Training and Development
- B1. Employees / Trades Technical Training
- B2. Career development

C. Behavior
- C1. Nonfinancial Incentive Programs
- C2. Financial Incentive Programs
- C3. Social Activities

D. Organizational Structure
- D1. Maintain Stability of Organization Structure
- D2. Clear Delegation of Responsibility

E. Employment
- E1. Retention Plan For Experienced Personnel
- E2. Exit Interview

V - CONSTRUCTION METHODS
A. Project Schedule Control
- A1. Integrated Schedule
- A2. Work Schedule Strategies
- A3. Schedule Execution and Management

B. Site Layout Plan
- B1. Dynamic site layout plan
- B2. Traffic Control Plan
- B3. Site security plan
- B4. Machinery & Equipment positioning strategy

C. Design/Construction Plan & Approach
- C1. Communications, Coordination, & Agreements
- C2. Project start-up plan
- C3. Project Completion Plan
- C4. Innovations & New Technologies
- C5. House Keeping

VI - HEALTH AND SAFETY
A. Job Site Safety
- A1. Formal Health and Safety Policy
- A2. Health and Safety Plans/Zero Accident Techniques
- A3. Task Safety Analysis
- A4. Hazards Analysis
- A5. Hazards Planning

B. Substance Abuse Program
- B1. Drugs and Alcohol Testing Program

C. Health and Safety Training & Orientation
- C1. Health and Safety Training Programs
- C2. Toolbox Safety Meetings

5 Scoring of the Infrastructure BPPII

Each element is scored based on its planning and implementation level (PIL). The PIL scale ranges from 0 to 5. A score of 0 is assigned to elements that are not applicable to the particular project. Elements that are applicable are assigned a score from 1 to 5, with 1 as no implementation and 5 as the highest possible implementation. Figure 1 shows an example of scoring sheet for the section of Procurement Strategy under the Materials Management category. Each of the level definition is different based on the definition of each element. Therefore, each element has a planning and implementation levels definitions that are specific to that element. This is used to eliminate user bias and create transparency. Figure 2 provides an example of element's description for Construction Machinery Productivity Analyses.

CATEGORY I: MATERIALS MANAGEMENT	**Planning and Implementation Level**					
SECTION A. Procurement Strategy	0	1	2	3	4	5
Elements						
1. Procurement Procedures & Plans for Materials & Equipment						
2. Long-Lead/Critical Equipment & Materials Identification						
3. Procurement Team						

Figure 1: Example of a Project Score Sheet in BPPII Infrastructure

Construction Machinery Productivity Analyses

Construction machinery plays an important role in optimizing productivity, project performance, capital efficiency, and cost. It enables the tasks to be performed efficiently and much faster. However, it is necessary to understand the costs and benefits associated with the use of construction machinery. Use of and availability of a particular piece of construction equipment affects the cost/benefit ratio associated with operating it. Issues to consider include:

- Measure utilization time (uptime) of construction machinery and equipment
- Measure delays due to unavailability of construction machinery
- Machinery use is adjusted with construction schedule and contingency plans available if the schedule changes

Level 0	Use of Construction Machinery is not applicable
Level 1	Construction Machinery is utilized but requirements and usage are not planned and tracked.
Level 2	Machinery requirements are planned and scheduled on a spreadsheet or tracking device but are not tied to a schedule. Usage is tracked against a budget activity.
Level 3	Continuations of Level 2, plus needs are reviewed regularly in planning meetings. A mechanism for resolving conflicts and allocation of machinery is established.
Level 4	Continuation of Level 3, plus schedule resource curves are driver in mobilization and demobilization of equipment on site. Schedule is resource leveled with consideration of minimizing in/out cycle of equipment and maximizing use.
Level 5	Continuation of Level 4, plus usage is audited and downtime reported and tracked, equipment schedule/plan adjusted as required based on audits.

Figure 2: Example of Element Description in the BPPII Infrastructure

It is important to note that while the PIL definitions differ for each element, they are defined to be consistent throughout the tool. This means that actual definition for each of the elements will differ, but the definitions for each will correspond to the same level of planning and implementation. A guideline for each PIL has been made, which is explained as below:

1. **Planning and Implementation Level 0:** The planning and implementation of the element is not applicable.

2. **Planning and Implementation Level 1:** The planning and implementation of the element is not addressed in any capacity on the project.
3. **Planning and Implementation Level 2:** The planning and implementation of the element is addressed up to a certain extent, but in a below average manner.
4. **Planning and Implementation Level 3:** The element has average level of planning and implementation.
5. **Planning and Implementation Level 4:** The planning and implementation of the element is thorough, above average, but not perfect.
6. **Planning and Implementation Level 5:** The element has the highest possible planning and implementation level, i.e. at most state of the art and technologically advanced level.

By using a weighted system, each element's PIL corresponds to a different score rather than a simple 0 to 5 scale. Figure 3 shows the weighted scores of elements for the section of Procurement Strategy. When PIL for all the elements are determined, then their weighted scores are obtained using the weighting system. The scores of the elements in a section are summed to obtain a section score, and the scores for all sections in a category are added to obtain the category score. Finally, all the categories' weighted scores are summed to obtain the total BPPII score.

SECTION A. Procurement Strategy	**Planning and Implementation Level**					
	0	1	2	3	4	5
Elements	**Weighted Scores**					
1. Procurement Procedures & Plans for Materials & Equipment	0	1	9	17	25	35
2. Long-Lead/Critical Equipment & Materials Identification	0	1	13	25	37	49
3. Procurement Team	0	1	5	9	13	19

Figure 3: Example of a Weighted Score Sheet in the BPPII Infrastructure

6 Data Collection and Analyses

6.1 Data Collection Tool

A survey questionnaire was developed to collect data for infrastructure projects. Information was collected for both the labour productivity and practices score in the index. The questionnaire collected information on the PIL of all the 61 elements in the index listed in Table 2. The respondents were not provided with the weighted scores of the elements, and they had to provide the PIL of the practices on the scale from 0 to 5 based on their detailed description, an example of which is provided in Figure 2.

Productivity Factor

The productivity factor was used as a metrics to measure labour productivity. The productivity factor (PF) is defined by equation 1:

$$[1]\ \text{Productivity Factor (PF)} = \frac{\text{Estimated Productivity}}{\text{Actual Productivity}}$$

Estimated productivity and Actual productivity are defined as estimated work-hours divided by estimated quantity and actual work-hours divided by actual quantity respectively. When using the above equation, the PF value of 1 and above is considered better, because less labour hours are required to complete a unit of work. Productivity factor information for concrete work was collected for infrastructure projects. The concrete work was selected, because it is a common work found in most of the infrastructure projects. The unit rate or actual productivity is a helpful metric in comparing projects when they are almost identical in all respects. Productivity factor was used instead of absolute productivity numbers because this measure allows projects to be compared in terms of productivity performance irrespective of their type, location, complexity, size, contract type and so on. It is a relative metric and is useful in this type of research work. It has also been recommended to compare productivity performance between projects, when it is difficult to obtain absolute productivity numbers from companies because of concerns about confidentiality and competitiveness (Nasir et al. 2012).

Data from 29 infrastructure projects were obtained for both the productivity factor and BPPII scores. Based on the characteristics of the projects reported in the Table 3, we can state with confidence that we had a fairly representative sample collected to perform the analyses. The data were collected from different companies working in different parts of the world. The projects represented different types of infrastructure projects, such as roads, bridges, water/waste water treatment plants, dams, and interchanges. The size of the projects also varied form less than a million dollars to over 100 million dollars. The projects were executed through different contract strategies.

Table 3: Distribution of Data

	Category	No. of Projects
Project Description	Water/Waste Water Treatment Plants	7
	Roads/Highways	12
	Dam(s)	3
	Interchanges	2
	Other Subcategory(metro rail, utilities)	5
Project Nature	Grass Roots, Greenfield	8
	Modernization, Renovation, Upgrade	19
	Addition, Expansion	2
Project Size	Less than 1 Million Dollars	1
	1 - 5 Million Dollars	8
	6 - 50 Million Dollars	10
	51 - 100 Million Dollars	4
	101 - 500 Million Dollars	5
	500 - Million Dollars	1
Scope of Construction Contract	Construct Only	19
	Design and Construct	1
	EPCM (Engineer, Procure, Construct, and Manage)	1
	Construction or Project Management Only	6
	Other (Please specify):	2
Type of Construction Contract	Fixed Price	17
	Unit Price	11
	Cost Plus % Fee	1

6.2 Weighting System of Infrastructure BPPII

One of the important steps in the development of the BPPII is the assigning of weights to each element, section, and category in the index. When all the elements had been identified and grouped into sections and categories, the next step in the development of the index was to assign weights to the elements, sections, and categories. These weights to elements are assigned based on their relative importance on affecting the productivity on infrastructure projects. Not all of the elements will have same effect on productivity; therefore, some of the elements will be assigned higher weights relative to others.

Weights were assigned first to categories relative to each other, based on their importance to the productivity after statistical analyses. The weights are assigned after conducting correlation analyses. Correlations analyses were performed to see the bivariate relationship between productivity factor and each of the six individual categories, which make up the index. This was done in order to find how the productivity factor is related to each individual categories and what the direction of the relationship is. Pearson's correlation coefficient is used to see the direction and strength of the relationship between two variables. The following steps explain the procedure followed in assigning relative weights. Un-weighted scores are used in each step from the data obtained.

Steps

Step 1: Pearson's correlation coefficients were calculated between productivity factor and each of the elements in the index.

Step 2: Scores of six categories were calculated after excluding the scores of elements with negative correlations between PF and individual practice element.

Step 3: Pearson's correlation coefficients were calculated between productivity factor and each of the categories in the index.

Step 4: Relative Importance Weights (RIW) were assigned to the categories based on the correlation coefficients using equation 2.

[2] *Relative Importance Weights (RIW)* = $\frac{r_i}{\sum_{i=1}^{n} r_i} \times 100$

where r_i = Pearson's correlation coefficient, and n= 6 (for 6 categories)

The RIW for each category is obtained as the ratio between the individual score and the total scores of all categories on the basis of correlation coefficients.

Step 5: Relative weights were assigned to sections in the categories and elements using the same process as described in step 4 for assigning weights to categories.

The un-weighted scores for each category were normalized by considering only those elements which were applicable in the category and excluding those not applicable. Then, their bivariate correlations with productivity factor were calculated using excel and SPSS. Table 4 provides the relationship between productivity factor and the six categories of the index along with their significance levels. It should be noted that those elements/practices which had shown negative or weak correlation with productivity factor were still allowed to be part of the index. These elements were assigned less weights relatively to others. Although there is sufficient data to conduct analyses; however, the elements should be taken out of the index only when we have data from a very large number of projects.

Table 4: Correlation Coefficients

		PF	MM	CMEL	EA	HRM	CM	HS
PF	Pearson Correlation	1	.253	.409*	.617**	.673**	.577**	.683**
	Sig. (2-tailed)		.213	.038	.001	.000	.002	.000

N = 26 *. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

(PF = Productivity Factor; MM = Materials Management; CMEL = Construction Machinery and Equipment Logistics; EA = Execution Approach; HRM = Human Resources Management; CM = Construction Methods; HS = Health and Safety)

A rule of thumb is that a correlation between 0 to just less than 0.30 is a weak correlation, a correlation of 0.30 to 0.50 is considered moderate, and over 0.50 is considered a strong correlation (Cohen, 1988). Based on these results, materials management was found to be the only category to have a weak correlation with productivity. The categories of Execution Approach, Human Resources Management, Construction Methods, and Health and Safety were found to have a strong correlation with productivity and have a significance level of 99%. The category of Construction Machinery and Equipment Logistics has a moderate relationship with productivity at a significance level of 95%. One reason for the weak correlation between materials management and productivity compared to other categories could be that materials used on most of the infrastructure projects are common or bulk materials and are easily available.

6.3 Regression Analysis

Regression analysis was performed to investigate the relationship between the BPPII score and productivity score. The un-weighted BPPII scores were transformed to the weighted scores based on the relative weights assigned to each element as explained above. Figure 4 shows the scatter plot between BPPII score and PF. The R^2 has a value of 0.405, which shows that over 40% of the variability in the PF is explained by the BPPII score. It should be noted that there are other factors besides best practices, which can influence productivity, such as acts of nature, social, political, and economic conditions, government policies, and so on. Table 5 provides the results of the regression analysis. The model is found to be statistically significant at 99% confidence level.

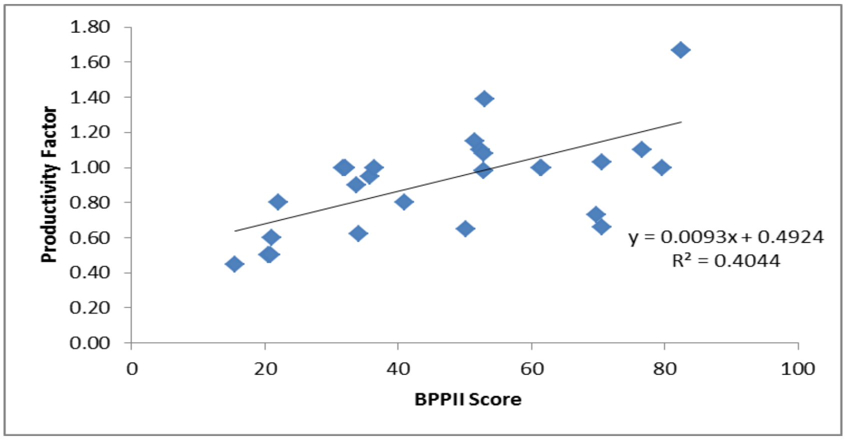

Figure 4: Scatter Plot between BPPII Score and Productivity Factor

Table 5: Regression Statistics and ANOVA

Model Summary					ANOVA					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Model	Sum of Squares	df	Mean Square	F	Sig.
1	.636	.405	.383	.23538	Regression	1.016	1	1.016	18.347	.000
					Residual	1.496	27	.055		
(Predictors: BPPII Score, Dependent Variable: PF)					Total	2.512	28			

7 Conclusions and Recommendations

Based on the analyses presented above, it can be concluded that the higher level of implementation of best practices can improve productivity in the construction industry. Positive relationship was found between all the categories of the index and productivity. Over all the BPPII score was found to have a strong relationship with productivity improvement and the regression analysis shows that 40% of the variance in productivity factor can be explained by the index score. Between individual categories, Materials management was found to have less positive correlation, and Construction Machinery and Equipment Logistics has a moderate correlation with PF. The other four categories of Execution Approach, Human Resources Management, Construction Methods, and Health and Safety were strongly correlated to productivity at a significance level of 99%. It is recommended that a similar tool should be developed based on the planning and implementation level of best practices for the building sector of the construction industry to cater for its specific needs and nature. It is also recommended that a database should be created for labour productivity information in terms of actual and estimated productivity (unit rates) for different types of infrastructure projects to help in benchmarking the productivity of projects having similar characteristics to avoid unbiased conclusions.

8 References

ASCE (2009). *"Report Card for America's Infrastruture*." Available at http://www.infrastructurereportcard.org/, last accessed on 06 December,2010

Canada's Economic Action Plan (2010). *Year 2, A Sixth Report to Canadians, Government of Canada*, Cat. No.: F2-189/6-2010E-PDF, ISBN 978-1-100-17000-8 Available at http://www.fin.gc.ca/pub/report-rapport/2010-09-27/pdf/ceap-paec-2010-09-eng.pdf , last accessed on 23 November 2010.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioural Sciences.* New Jersey: Lawrence Erlbaum Associates

Construction Industry Institute (CII) (2006). CII Best Practices Guide: Improving Project Performance, Implementation Resource 166-3, Second Edition, Austin, TX.

Construction Industry Institute (CII) (2009). "Research Summary – Phase I of the Craft Productivity Research Program." Publication 252-2. The University of Texas at Austin.

Costa, D.B., Formoso, C.T., Kagioglou, M., Alarcon, L.F., and Caldas, C.H. 2006. Benchmarking initiatives in the construction industry: Lessons learned and improvement opportunities. *Journal of Management in Engineering*, ASCE, Vol. 22 No. 4, 158-167.

Dai, J., Goodrum, P. M., & Maloney, W. F. (2009). Construction Craft Workers' Perceptions of the Factors Affecting Their Productivity. *Journal of Construction Engineering and Management* , 135 (3), pp. 217 - 226.

Hwang, B.G., Thomas, S.R., Haas, C.T., and Caldas, C.H. (2009). "Measuring the impact of rework on construction cost performance." *Journal of Construction Engineering and Management*. ASCE. 135(3). pp. 187-198.

Independent Project Analysis (IPA) (2010). Web site available at: http://www.ipaglobal.com/About-Us last accessed on 18 October 2010

Kazaz, A., and Ulubeyli, S (2007). Drivers of productivity among construction workers: A study in a developing country *Building and Environment* 42, 2132–2140.

Lozon, J. and Jergeas, G. (2008). "The use and impact of value improving practices and best practices." *Cost Engineering*, Vol. 50 (6), pp. 26-32.

Mirza, S. 2007. *Danger Ahead: The coming collapse of Canada's municipal infrastructure*. A report for the Federation of Canadian Municipalities, November 2007.

Mohammadian, R. and Waugh, L. (1997). "Productivity adjustment in construction price indexes." Statistics Canada, Analytical Series, Prices Division, *Catalogue No. 62F0014MPB, No. 3.*

Nasir, H., Haas, C., Rankin, J., Fayek, A.R., Forgues, D., and Ruwanpura, J. (2012) "Development and Implementation of a Benchmarking and Metrics Program for Construction Performance and Productivity Improvement." *Canadian Journal of Civil Engineering*, Special Issue on Construction Engineering and Management, Vol. 39(9), pp. 957-967,

National Research Council (NRC) (2009). "Advancing the competitiveness and efficiency of the U.S. construction industry." The National Academies Press, Washington, DC.

Rojas, E. and Aramvareekul, P. (2003). "Labor Productivity Drivers and Opportunities in the U.S. Construction Industry." Journal of Management in Engineering, ASCE, 19 (2), 78-82.

Tabassi, A.A., Ramli, M., Abu Bakar, A.H. (2012). Effects of training and motivation practices on teamwork improvement and task efficiency: The case of construction firms *International Journal of Project Management* 30, 213–224.