PROBABILITY DENSITY FUNCTION FOR PREDICTING PRODUCTIVITY IN MASONRY CONSTRUCTION BASED ON THE COMPATIBILITY OF A CREW

Laura Florez[1], Jean C. Cortissoz[2]

1 BACKGROUND AND IDENTIFICATION OF PROBLEM/KNOWLEDGE GAP

Personality factors have been demonstrated to be useful for explaining and predicting attitudes, behaviors, job performance, and outcomes in many organizational settings (Ones et al, 2007; Shuck and Reio, 2013; Hogan and Holland, 2003; Campion et al, 2005; Cohen and Bailey, 1997). The big five personality dimensions OCEAN (Goldberg, 1993) have been investigated in meta-analytic studies (Hogan and Holland, 2003; Cohen and Bailey, 1997), and have been used in applied psychology and human resource management to determine the relationship between personality and job performance.

In construction, groups of workers are known as crews. Crews specialize in a given skill to complete a task (Ng and Tang, 2010), and the foreman in the jobsite is responsible of forming crews to maximize productivity. Decisions on how to form crews and what is the proper grouping of workers to increase productivity in construction have been addressed by a number of studies (Nerwal and Abdelhamid, 2012; Mitropoulos and Memarian, 2012; Hassanein and Melin, 1997; Rojas 2008). These studies provide clear guidelines and specific characteristics that need to be considered to form lean and effective crews. However, the current crew formation literature in construction lacks of a framework that considers personality factors and how the interpersonal compatibility between workers in a crew can be used to form effective crews and predict productivity.

2 RESEARCH AIM AND METHODOLOGY

This paper proposes a mathematical framework to determine how the compatibility between workers in a crew can be used to predict productivity. A probability density is empirically defined to predict productivity. The probability density determines, for a given compatibility, the average productivity for a crew and can be used to better estimate times of construction.

Figure 1 shows the mathematical framework that supports masonry contractors in the process of predicting productivity. To obtain productivity estimates, a series of steps need to be followed (see Figure 1). Firstly, a literature review was performed for definitions of the OCEAN factors. Based on these factors, masons complete a test to indicate and quantify their personality. Based on their personality, the foreman determines a compatibility score for all the possible crew formations. After defining the compatibility score, measurements on-site are conducted to measure the productivity for multiple crews that have the same compatibility score. From the field measurements, the productivity density function is developed, that is, an average productivity can be estimated for crews that share similar compatibility. The distribution, alongside the confidence intervals, can be used to better predict productivity, estimate times of construction, and determine productive crew formations.

[1] Senior Lecturer, Faculty of Engineering and Environment, Northumbria University, Newcastle Upon Tyne, UK, laura.florez@northumbria.ac.uk

[2] Associate Professor, Department of Mathematics, Universidad de los Andes, Bogotá, Colombia, jcortiss@uniandes.edu.co

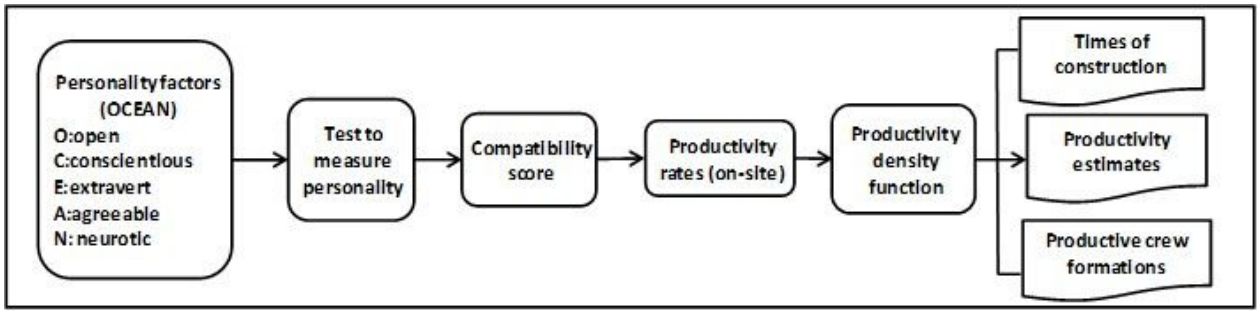

Figure 1: Mathematical framework.

To illustrate how the personality of the masons determines the compatibility of a crew and how the compatibility can be used to predict productivity, let's assume that crew 1 will build wall 1. Crew 1 has three masons and its compatibility score is 0.5. On the other hand, wall 2 is built by crew 2 and crew 2 has four masons and a compatibility score of 1.0. The productivity data has been collected empirically for crew 1 and crew 2 (see Table 1 and Table 2). Crew 1 (compatibility of 0.5) lays blocks at the following rates per period of time (see Table 1). Crew 2, (compatibility of 1.0) lays blocks at the following rates (see Table 2). We will assume that a crew keeps the same productivity rate until the wall is finished. Wall 1 has 500 blocks, and wall 2 has 1000 blocks thus the data can be converted into data of how long it will take each crew to finish wall 1 and wall 2.

Table 1: Productivity rates for crew 1

Number of units	Probability
220	0.20
250	0.30
270	0.30
290	0.10
300	0.10

Table 2: Productivity rates for crew 2

Number of units	Probability
450	0.30
470	0.30
490	0.30
500	0.10

We then can compute the mean and variance for the units of time it takes each crew to finish a wall, so for crew 1 the units of time X that it will take to complete wall 1 has a mean of X = 1.948, whereas the units of time Y that crew 2 takes to complete wall 2 has a mean of Y = 2.117. Second we compute the variance of both distributions and we obtain 0.037 and 0.006 for X and Y, respectively. As we have assumed that wall 1 should be completed before starting wall 2, then the two walls are expected to be completed in $x + y = 1.948 + 2.117 = 3.065$ units of time. Now, as the two walls are different, we may assume that the random variables x and y are independent, so its probability density is given by:

$$Px + y(z) = \frac{1}{\sqrt{2\pi * 0.043}} \exp\left(-\frac{(z - 3.065)^2}{2 * 0.043}\right)$$

With the function given above, we can make more accurate predictions such as the probability that it will take more than 3.5 units of time to complete both walls.

3 RESEARCH FINDINGS

- Personality has been found to be a key parameter to form crews.
- A framework was proposed to determine the interpersonal compatibility of a crew and define a productivity density function to predict productivity.
- The proposed productivity density function supports foremen and contractors to estimate times of construction, avoid crew conflicts, and find practical ways to increase productivity.