UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS DE CAMINOS, CANALES Y PUERTOS

Study on Improving Labor Productivity in the Construction Industry. The Cases of Europe and Hong Kong.

TRABAJO FINAL DE GRADO

Titulación: Grado en Ingeniería Civil

Curso: 2015/16

Autor: Ignacio ZABALLOS PALOP

Tutor: Victor YEPES PIQUERAS

Cotutor externo: Xueqing ZHANG

Valencia, junio de 2016

GENERAL INDEX

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR DE INGENIEROS DE CAMINOS, CANALES Y PUERTOS

DOCUMENT Nº1: MEMORY AND APPENDICES

Study on improving labor productivity in the construction industry. The cases of Europe and Hong Kong.

Titulación: Grado en Ingeniería Civil

Curso: 2015/16

Autor: Ignacio ZABALLOS PALOP

Tutor: Victor YEPES PIQUERAS

Cotutor externo: Xueqing ZHANG

Valencia, junio de 2016

ABSTRACT

Labor productivity is one the least studied areas within the construction industry. Productivity improvements achieve high cost savings with minimal investment. Due to the fact that profit margins are small on construction projects, cost savings associated with productivity are crucial to becoming a successful contractor. The chief setback to improving labor productivity is measuring labor productivity.

However, labor productivity involves many aspects. The aim of this research is to focus in some of them such as construction trades and how different factors affect their labor productivity through benchmarking in both online and hard copy format. A list of 37 construction trades was selected based on the Construction Industry Council of Hong Kong (CIC) in order to see their construction cost, labor cost and labor shortage criticality and their automation level. A list of 40 factors affecting the labor productivity was selected based on experts at The Hong Kong University of Science and Technology, in order to see in which level they affect the critical construction trades labor productivity found previously. Both results were analyzed using the relative importance index (RII).

These results are used in an additional case study, based on the comparison of them with another study with the same objectives did by some colleagues from The Hong Kong University of Science and Technology. An additional improvement of the labor productivity can be done by the mixture of both studies.

Results found previously can be used in a future study to create a tool to help contractor’s grade productivity on their projects in the preplanning stage and plan improvements in the most beneficial areas.

ACKNOWLEDGEMENTS

It is my pleasure to thank my adviser, Dr. Xueqing Zhang, from the Hong Kong University of Science and Technology, who made this research paper possible with his commitment, supervision, patience and support from the commencement of the research to its conclusion. I have enjoyed working with him and appreciate the support and opportunities he provided.

I would like to thank my supervisor Dr. Victor Yepes from my home university, Universidad Politécnica de Valencia, for his commitment helping me from the distance and the university itself for the opportunity given through the mobility grant, PROMOE. Also, I thank the international department of the ETSICCP for their continued support.

I also extend my sincere gratitude to all the research study's respondents for their valuable inputs; my partners doing the same study for the case of Hong Kong and the PH student Wei Zhang for his kindly support.

Special thanks to my family, for always believe in me and give me the courage to tackle a project abroad.

LIST OF TABLES

LIST OF FIGURES

Table of contents

CHAPTER 1. INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

Construction is one of the nation's largest industries of the world and has been playing a significant role in socio economic development, as well as in reducing unemployement. Productivity is one of the important aspects for the companies in the construction industry. Improvement in the productivity of the construction industry is therefore of critical importance considering its significant contribution to the GDP (Gross Domestic Product). In Europe, the construction industry, including contractors, manufacturers of construction products and professional construction services, generates 10% of the GDP (Gross Domestic Product) and provides 20 million direct jobs. (Beatriz Velazquez, European Union, 2013). Values that will constantly grow until 2020 according to forecasts by many analysts.

Several studies related to labor productivity are performed for the construction industry in past. Several of them were related to calculating the effect of productivity factors and monitoring systems. Measurable calculations about the effects of those factors are required for several purposes, it includes estimation of the construction project, it's planning and scheduling. However, past study shows that it is tough to calculate such an impact, and at present, there are no universally accepted standards to measure factors causing labor productivity loss in the construction industry.

This lack of methods for measuring effects highlights the need to enhance other methods for improving the labor productivity in the construction productivity. Achieving better labor productivity requires detailed studies of the actual labor cost. Various labors have different variables affecting their productivity levels. Due the lack of studies about the labor cost of the different construction trades in this area, this research will focus on it. A research passing the mixture of the importance of the factors affecting the labor productivity on a series of critical construction trades; a method that is supposed to be the topic of this research. The construction company with the most efficient operations has a greater chance to make more money and deliver faster construction project to the project owner. Improving labor productivity can alleviate the shortage of skilled craft-workers, enhance the working conditions, and enhance the overall quality of a product.

For every project, productivity, cost, quality and time have been the main concern. Better productivity can be achieved if project management includes the skills of education and training, the work method, personal health, motivational factors, the type of tools, machines, required equipment and materials, personal skills, the workload to be executed, expected work quality, work location, the type of work to be done, and supervisory personnel (Rowlinson and Proctor, 1999).

A successful construction project is one that is completed on time, within budget, meets specified standards of quality, and strictly conforms to safety policies and precautions. All of this is feasible only if the premeditated levels of productivity can be achieved. All the same, productivity, or lack thereof, is one of the construction industry's most prevalent problems. Due to the nature of construction projects, its importance to society and the existing economic resources, more emphasis should be given to improving productivity.

An increase in the productivity of the construction sector should not only raise the earnings and profits of those working in that sector but also contribute to an improvement of the productivity in other sectors, thereby improving generals standards of living.

1.2 BACKGROUND ABOUT PRODUCTIVITY

The term of "Productivity" has different meanings for different people. Depending on who is explaining productivity, whether he is a politician, accountant, economist, industrial engineer, or construction manager, you will get a wide range of different meaning of the term "Productivity". Some will define it as production rate, efficiency, effectiveness, performance or merely production.

Productivity is generally defined as the average direct labor hours required to install a unit of material. It is said that perfect productivity (1.0) can be achieved with a 40-hour work week, with people taking all the holidays and vacation days as planned, all of the engineering drawings would be 100% complete and no delays of any kind during construction; everyone would work safely; everything would fit perfectly the first time; the weather would be 70o F; and there would be no litigation at the end of the project (Rowlinson and Proctor, 1999).

Construction requires extensive manual labor. Human performance and productivity are reliant on one another. Therefore, the most commonly used measure of productivity is the constant contract dollars of new construction work per work hour (Hendrickson 1998). A study by Teicholtz (2004) revealed that over 40 years (1964-2003) the construction industry lags compared to all other non-farm industries in developing and applying labor saving techniques and substituting equipment for labor.

Following several researches about the construction productivity, there are a few facts (2016; Sudam Chavan and Hemant Salunkhe; 1998, Paul O. Olomolaiye, Anando K.W. Jayawardane and Frank C. Harris):

i. Tuesday is studied as most productive day of the week.

ii. 10 a.m. is studied as most productive time of the day.

iii. A laborer is capable of lifting approximately 94 pounds on his own.

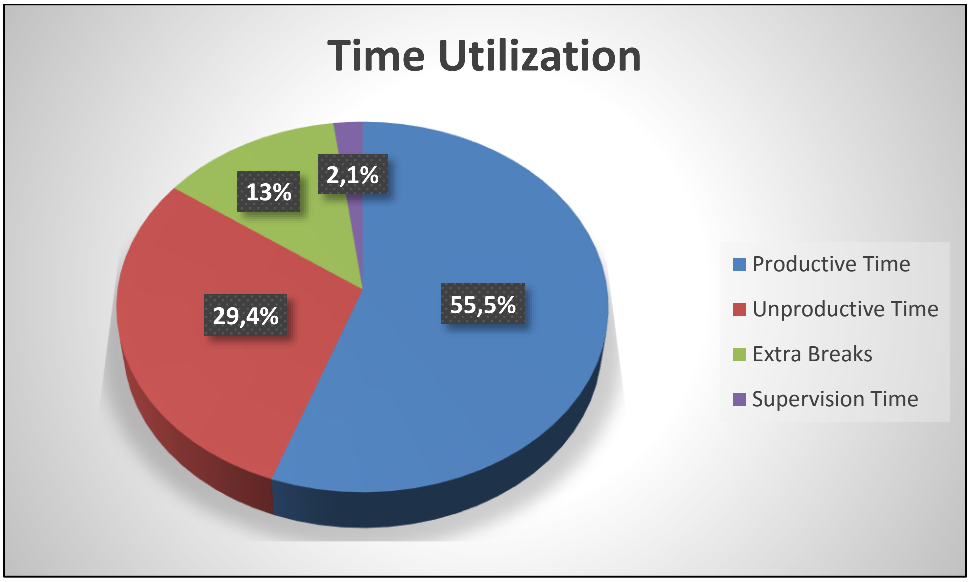
iv. The least productive time frame for labor is right before the finishing time.

v. If the laborer is engaged in performing the same task repeatedly, there is a chance of low productivity after 60-70 minutes of performing the same work.

vi. Friday has been proven to be the least productive day of the week.

vii. The time utilization of the average construction worker: 55.5% productive time, 29.4% unproductive time, 13% extra breaks and 2.1% supervision time.

Figure 1. Time utilization of a worker in Europe



1.3 DEFINITION OF PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

Back in 1986, Thomas and Mathews (1986) stated that no standardized productivity definition had been established in the construction industry. It is difficult to define a standard productivity measure because companies use their internal systems which are not standardized. Output and input differ from one industry to another. Also, the productivity definition varies when applied to different areas of the same industry. Productivity can be simply illustrated by an association between an output and an input (Park H S.2006). Productivity is defined as the ratio of output to input, that is the ratio of the amount produced (the output) to the amount of any resources used in the course of production (the output). The resources may be land, materials, machinery, tools or manpower. The input is generally a combination of all of them. Productivity increases if a greater output is achieved for the same output, or if the same output is achieved for a smaller input. If input rises in direct proportion to output, then productivity will stay the same.

Labor is one of the basic requirements in the construction industry. Labor productivity usually relates manpower in terms of labor cost to the quantity of outputs produced (Borcherding and Liou, 1986). In construction, productivity is usually taken to mean labor productivity, that is, units of work placed or produced per man-hour. The inverse of labor productivity, man-hours per unit (unit rate) is also commonly used.The overall productivity in construction has been greatly affected by regulatory controls, environment, climatic effects, the cost of energy, and other factors.

The construction industry is a more complex and fragmented industry. Construction activities are generally complex due to the vast number of tradesmen, materials, machinary and construction methods used in any one construction project causing difficulty in controlling efficacy and cost. The industry is also highly fragmented with different transient professionals (project consultants), builders and suppliers entwined in different procurement and contractual arrangements. Unique “one-off” nature of construction operations, the final product of construction is usually unique design and often differs from one project to another. Each new project needs to be designed separately even though their functional attributes may be similar. It is focused on the end of the product or facility rather than on improvements in materials or methods.

Construction labor productivity is affected adversely internally by an ineffective organization of work, and lack of information feedback system relating to productivity and externally by social legislations, and cost of energy.

1.4 CONSTRUCTION LABOR PRODUCTIVITY MEASUREMENT

Different measures of productivity serve different purposes. It is important to choose a measure that is appropriate to the purpose. Labor productivity can be assessed by stopwatch time study, fundamental motion data, standard data, time formulas, or work sampling studies. Indirect labor productivity for clerical, maintenance, tool making or housekeeping activities may be assessed by using standard data, formulas or operations research techniques. Horner and Duff (2001) found that the productivity of two gangs doing identical jobs on the same site and at the same time could vary by up to 50 percent and the productivity of two gangs doing identical jobs in different sites could vary by 500 percent

As it has been described in the previous section, two forms of productivity were used in previous industry studies:

(1) The first form has been widely used in the construction industry and the existing literature:

$$\mathbf{Productivity} = \frac{\boldsymbol{output}}{\boldsymbol{input}}$$

(2) The second form has been usually for estimating

$$\mathbf{Productivity} = \frac{\boldsymbol{input}}{\boldsymbol{output}}$$

High productivity comes from no simply what resources an organization owns but how an organization uses, develops and combines them to produce unique internal and dynamic capabilities.

In terms of the number of variables in calculating productivity, there are two types of productivity: **total factor productivity** (TFP) and **single factor productivity** (CLP).

(3) Total factor productivity (TFP) or multi-factor productivity includes multiple factors such as labor, equipment, materials, and capital as inputs. Total factor productivity is usually used in economics studies and not in construction. The equation for TFP is:

$$\mathbf{TFP} = \frac{\boldsymbol{dollars\ of\ input}}{\boldsymbol{dollars\ of\ output}} = \frac{\boldsymbol{Labor + equopment + material + capital}}{\boldsymbol{total\ output}}$$

(4) In contrast, single factor productivity only considers one input to calculate productivity. Labor productivity that considers only labor as an input is commonly used in the construction industry (Woo, 1999). The equation is:

$$\mathbf{CLP} = \frac{\boldsymbol{input}}{\boldsymbol{output}} = \frac{\boldsymbol{actual\ work\ hours}}{\boldsymbol{installed\ quantity}}$$

As shown in the above equation, labor productivity is measured in actual work hours/per installed quantity; that is, the number of actual work hours required to perform the appropriate units of work. When defined in this manner, it should be mentioned that the lower the productivity measurement value, the better the productivity performance.

Compared with cost-based output measures (Eastman and Sacks 2008), measurement hourly output helps to avoid many external factors that cause cost variances, so the hourly output is commonly recognized as a more reliable measurement of productivity for construction operational activities.

(5) CLP (construction labor productivity) is defined as the ratio between production output and labor hours consumed to deliver the corresponding output:

$$\mathbf{CLP} = \frac{\boldsymbol{output\ quantity}}{\boldsymbol{total\ labor\ hours\ consumed}}$$

In particular, the measurement of construction productivity is problematic because of the heterogeneity of inputs and outputs in the industry and because of the need to measure input and output service quality. There is also problems in making international comparisons because of the absence of international classifications and conventions for measurements. A contractor is more likely to define productivity, where the units of output are specific for generic kinds of work; typical units are cubic yards, tons, and square feet.

There are many of productivity measurement techniques that can be utilized for measuring construction labor productivity. Productivity measurement can be most beneficial when various techniques are employed, such as activity sampling technique, foreman delay surveys technique, time study technique, motion analysis technique and group timing technique; between them. For productivity analysis, it is essential to identify the significant productivity factors, quantify them, and establish the relationship of these factors with each other.

1.5 PROBLEM STATEMENT

In the construction industry productivity loss is one of the greatest and severe problems. Present construction contracts lack enough to classify recompense for productivity loss due to field factors. Of various project-costs components such as labors materials and equipment's, labor component is considered the most risk. Whereas others components (equipment and material) are determined by the market price and are, consequently, beyond the influence of project management.

Labor cost in the construction industry is estimated to be about 33%- 50% of the entire project cost (Hanna et Al, 2005). Because labor is more variable and unpredictable than other project-cost components, it becomes necessary to understand the effects of different factors on labor productivity and their construction trades associated. An increase in productivity can reduce the labor cost in a direct proportion. It can either benefit or reduce a project's profit, making it of vital interest to the construction industry for its success (Hanna et al., 2005).

Previous researches confirm that productivity loss results from various factors, which includes but not limited to various variation in drawings, long hours of extra work, poor field management, and extreme climatic conditions (Mahes Madan Gundecha, 2012; Sudam Chavan and Hemant Salunkhe, 2016). In fact, these factors typically produce extra disturbances that affect productivity and are beyond the direct control of a contractor, resulting in productivity loss or extra work hours necessary to accomplish the task.

But there is no research about how these factors affect the critical construction trades in building and infrastructure projects, and how they should be managed to improve the labor productivity and reduce costs for those projects.

1.6 AIM AND OBJECTIVE

This case study aims to improve the construction productivity in Europe by establishing productivity benchmarks at the trade level through the continent, with the following objectives:

i. To determine ten most critical construction trades affecting the productivity of typical types of building and infrastructure projects in Europe;

ii. To develop methodology for measuring the productivity of the trades selected in (i) above;

iii. Based on the productivity performance of the selected trades, to establish benchmark indicators of the trades in terms of productivity;

iv. Views from the construction industry about various affecting labor productivity to the selected trades;

v. To compare and evaluate the productivity performance of the selected trades with that of other developed countries, in our case study it will be Hong Kong; and

vi. To make recommendations to improve labor productivity in construction.

In the end, this study will provide a weight of importance for each critical construction trade and a list of the factors affecting their labor productivity. These weights will then be used to make recommendations to enhance project productivity. Furthermore, this research will serve to create an example tool in which the weights derived will be used to help project managers and top decision makers assess the current productivity issues on their projects from the pre-planning stage through the project's completion.

1.7 RESEARCH STRUCTURE

The research study aims to provide knowledge construction trades that affect the project's success and consists of five chapters and appendices (survey questionnaires).

Chapter 1: discusses the background, various definitions, measurement, problem statement, facts related to productivity and the aim and objectives of the study.

Chapter 2: discusses the research methodology used, elaboration of the questionnaire surveys, data collect and the analysis method.

Chapter 3: discusses the organization of the construction trades benchmarking for Europe, the analysis did and they rank by criticality cost, labor shortage and automation.

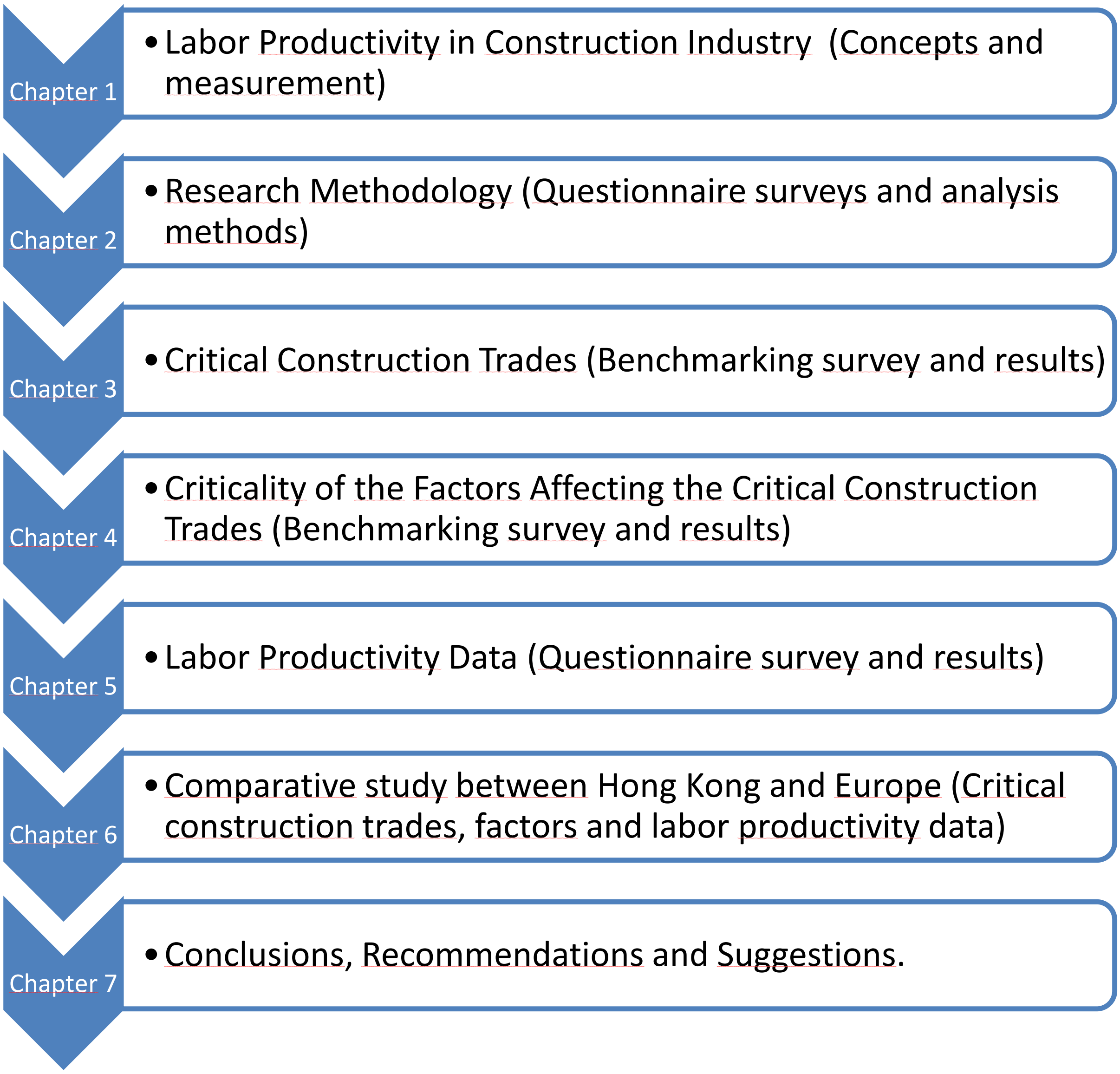
Chapter 4: discusses the questionnaire organization of the factors affecting the critical construction trades of Hong Kong and the analysis method and results for further comparatives with my partner's study.

Chapter 5: discusses the organization of the questionnaire for collect data of the labor productivity of the critical construction trades in Hong Kong for further comparatives with my partners study.

Chapter 6: discusses the study comparative between the benchmarking results obtained through Europe and Hong Kong, for the critical construction trades, data labor productivity and affecting factors.

Chapter 7: discusses conclusions, recommendations, and suggestions for future research.

Figure 2. Flow Chart showing the research structure



CHAPTER 2. RESEARCH METHODOLOGY

The research was conducted by structured questionnaires that were sent to different companies, departments and organizations through Europe, related to the construction. Countries we assume that the construction habitues will be similar and the results through benchmarking have less variability.

Benchmarking can be defined as “a systematic and continuous measurement process; a process of continuously measuring and comparing an organization’s business process anywhere in the world to gain information which will help the organization to take action to improve its performance”.

This is commonly called “external benchmarking”; when benchmarking is carried out with similar or identical organizations elsewhere, the salient point being the high degree of comparability between organizations. They may be direct competitors or similar organizations in other countries serving different markets but the approach will be considerably different depending on the partner’s market, in our case, the construction.

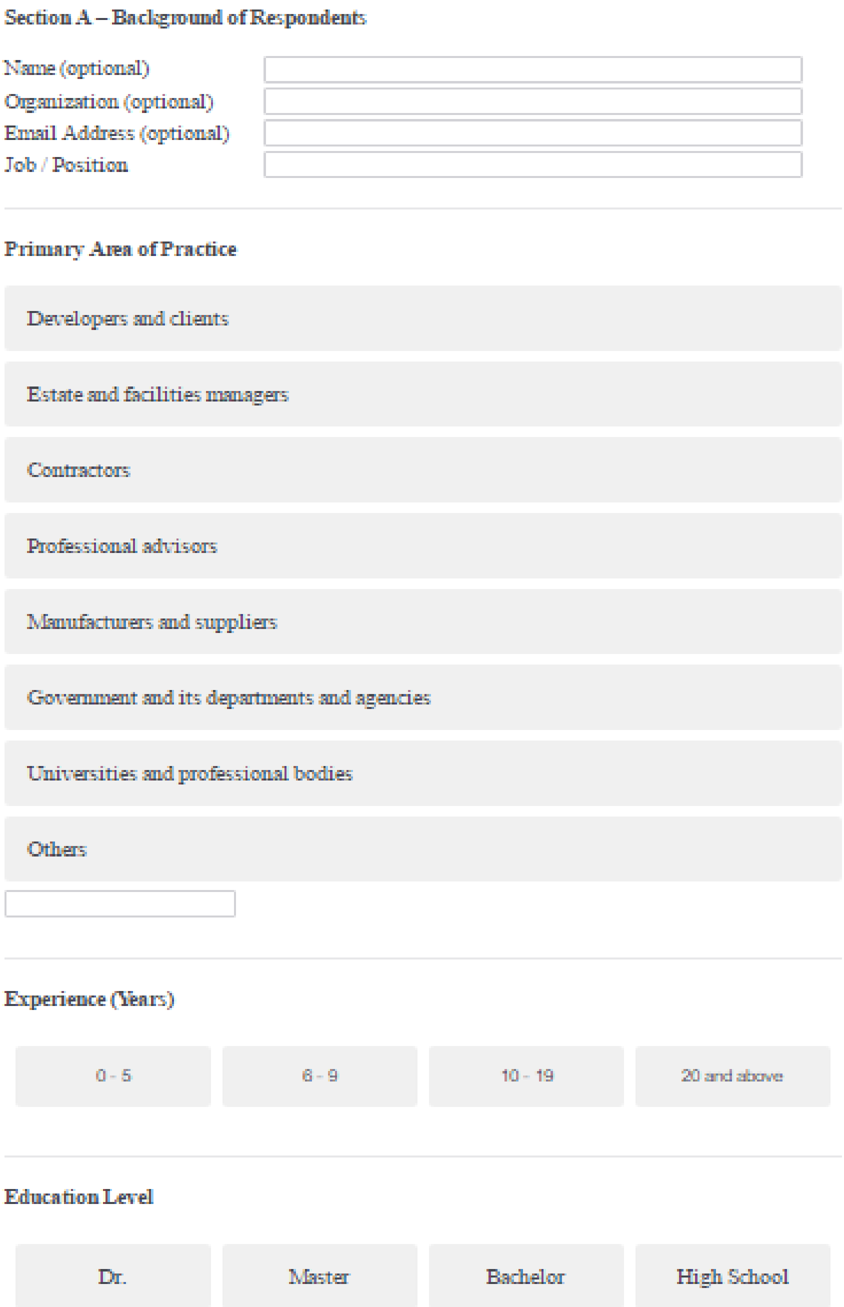
2.1 QUESTIONNAIRES PLANNING

For the research study, email technology was used to send the survey questionnaire given the size of the region to study, and the impossibility of surveying all the respondents in person. Given this circumstance, the questionnaires have been carried out in two different ways and can be made of any form as follows:

i. Hard-copy of the questionnaires in Word version to do it in writing, send by email. It can be returned scanned by email or by postal mail to the address indicated on it.
ii. Web-survey format, which requires less duration and comfort for the respondent. The surveys were carried out through the “Qualitrics Survey Software” of The Hong Kong University of Science and Technology. A software that provides analysis of the data collected.

All the questionnaires have been carried out in the same format, in order to make further comparisons and correlations between them. On the first page, the purpose, approach and confidentiality used in the survey are fully explained to the respondents. On the second page, we look for the background of the respondents: name; organization; email address; job / position; primary area of practice; experience (years) ; education level. After a page break, the questionnaire itself correspondent to each case with an indication of how it should be completed to reduce errors, which will be explained in further chapters. Finally, a page where we thank the respondents for their time spent doing the survey and notifying them that their responses have been properly registered.

Figure 3. Surveys section A – Background of Respondents



Section A – Background of Respondents

Name (optional)
Organization (optional)
Email Address (optional)
Job / Position

Primary Area of Practice

Developers and clients
Estate and facilities managers
Contractors
Professional advisors
Manufacturers and suppliers
Government and its departments and agencies
Universities and professional bodies
Others

Experience (Years)

0 - 5 | 6 - 9 | 10 - 19 | 20 and above

Education Level

Dr. | Master | Bachelor | High School

In terms of organization, the web survey was created using a light appearance and pleasant-looking font colors. All the information entered via the web had an auto-save.

2.2 CONSIDERATIONS FOR THE SURVEYS

The two main considerations for the surveys were that it should be easy and clear for respondents and that the respondents should be related to the construction industry in Europe. If questions are too complicated, the possibility of high drop-out rate was studied. A preliminary text was introduced for explaining the survey project to the respondents. Page breaks on the web pages were introduced to improve the text readability. Logic-based questions were avoided because they could cause respondent frustration and increase the drop-out rate. The data were stored in order to maintain confidentiality. Finally, to ensure access to the survey for the people selected, the questionnaires are always sent in word version format and web-survey format.

2.3 QUESTIONNAIRE DISTRIBUTIONS

The target groups in this study were professionals from the construction industry, from differents primary area of practice as follows: developers and clients; estate and facilities managers; contractors; professional advisors; manufacturers and suppliers; government and its departments and agencies; universities and professional bodies.

The method of people search and contact with them has been made over the internet. The simplest has been for those related to the university bodies. First, find those universities with a construction engineering and management department or similar, for after getting the emails from people working in these departments through the university directory. In relation to government and agencies, each European country has its own website and contact details; the problem found has generally been that many countries only have the website in their own language without any translation. Finally, obtaining contact details of companies in the private sector has been the most problematic because of their confidentiality. Normally, only it has been able to get the email of human resources; which is why other modes of contact have been used, such as Linkedin, where companies have their own profile with their members and it’s possible to send a message.

2.4 DATA COLLECTED FROM THE QUESTIONNAIRES

In successfully achieving the main objective of the study, one of the most important phases is the collection of accurate data. Data collection is a procedure of collecting crucial data records for a certain sample or population of observations (Bohrnstedt and Knoke, 1994).

Questionnaires being incomplete for the most part have been removed immediately from the set. Then, it has been observed that the background of the respondent is consistent with what we sought, and the IP address corresponds to a European country in case it is completely anonymous (otherwise it can be a European worker in a job outside the study region). Another consideration was the time they spent doing the survey. Finally, it has been observed that the responses are coherent and have not been put randomly or without knowledge of the subject. The accurate data collected has been introduced in Microsoft Office Excel for further analysis.

2.5 MEASUREMENT OF DATA COLLECTED

In order to select the suitable technique of study, the level of measurement is to be studied. For each measurement type, there is (are) (an) appropriate method(s) that can be applied. In this research, ordinal scales were used. An ordinal scale is a ranking or a rating of data that normally uses integers in ascending or descending order.

Three questionnaires have been conducted in this study. In one of them (more details in chapter 5), the respondents must enter a value of productivity for a given set of construction trades. In the other two surveys (more details in chapters 3 and 4), the respondent must rate the construction trades or factors entering a value between one and five in order to have a standard scale as follows:

(1) The relative criticality (“1” – Not Critical, “2” – Fairly Critical, “3” – Critical, “4” – Very Critical, “5” – Extremely Critical)

(2) The current level (“1” – Very Low, “2” – Low, “3” – Normal, “4” – High, “5” – Very High).

The numbers assigned (1, 2, 3, 4, 5) neither indicate that the intervals between scales are equal, nor do they indicate absolute quantities. They are merely numerical labels.

2.6 ANALYSIS METHOD USED

Once the data collected are representative, begins the analysis process to obtain the desired objectives of the study.

The data received is introduced at Microsoft Office Excel, a program who provides fast analysis and clear graphs showing the results. Two different ways were used to analyze the survey results:

i. For the questionnaires of chapters 3 and 4, the construction trades or factors were ranked by importance attending the Relative Importance Index (RII) method.

$$\boldsymbol{RII} = \frac{\sum \boldsymbol{W}}{\boldsymbol{A} * \boldsymbol{N}}$$

Where, *RII:* *Relative Importance Index*

W: *is the weight given to each factor by the respondents and ranges from 1 to 5 (where 1 is the lowest and 5 the highest).*

A: *is the highest weight (in this case is 5)*

N: *is the total number of responses collected for the ordinal scale.*

For a five-point response item, the relative importance index (RII) produces a value ranging from 0.2 to 1.0.

ii. For the questionnaire of chapter 5, the productivity ranges obtained are analyzed by the statistical average method.

$$\boldsymbol{P} = \frac{\sum \boldsymbol{V}}{\boldsymbol{N}}$$

Where, *P:* *is the average value of productivity looked.*

V: *is the productivity values for the differents construction trades.*

N: *is the total number of responses collected.*

For a five-point response item, te average produces a value ranging from 1 to 5.

CHAPTER 3. IDENTIFYING THE CRITICAL CONSTRUCTION TRADES IN EUROPE

3.1 CASE STUDY

This chapter aims to improve the construction productivity in Europe by establishing productivity benchmarks at the trade level through the continent with the following objectives:

i. To determine ten most critical construction trades affecting the productivity of typical types of building and infrastructure projects in Europe;

ii. To determine additional rankings for those construction trades based on labor shortage and automation levels;

iii. To determine the previous critical construction trades in Europe in order to make comparisons with those found in a previous study by my colleagues in Hong Kong and further researches related to them; and

iv. To determine the importance of benchmarks for data collection.

3.2 MAIN CONSTRUCTION TRADES DESCRIPTION

The chosen operations are based on the Construction Industry Council of Hong Kong (CIC), and the definitions/descriptions of each trade are provided in the following table. The reason why the trades are chosen through the CIC is to be the same as in the study previously begun by my colleagues in Hong Kong, so we can have standardized scales for the benchmarking and the comparatives.

The CIC is a platform to strengthen the sustainability of the construction industry in Hong Kong by providing a communications platform, striving for continuous improvement, increasing awareness of health and safety, as well as improving skills development.

Table 1. Main construction trades descriptions

No.	Trade Name	General Definition
1	Bar Bender & Fixer [or Steel bender]	To cut, bend and fix reinforcement steel bars according to drawings and bending schedules.
2	Concrete and Grouting Worker	To mix, place and compact concrete using vibrating machines; to carry out curing, leveling and smoothening of concrete.
3	Drain and Pipe Layer	To lay and join underground drains, construct manholes, install pipes and fittings, construct beds and haunches, and surround pipes with concrete. To lay water mains, make pressurised joints by mechanical means, install pipes and fittings, construct beds and haunches, and surround pipes with concrete.
4	Woodworker	Woodworking is the activity or skill of making items from wood, and includes cabinet making (Cabinetry and Furniture), wood carving, joinery, and carpentry.
5	Leveller	To read and interpret drawings; to set up job lines and levels and prepare templates.
6	Scaffolder	To erect and dismantle bamboo scaffolding required in construction, repair or decoration work, and other forms of structures.
7	Hand-dug Caisson Worker	Work at any foundation or earth-retaining structure, or part thereof, the construction of which includes the excavation of a shaft in the ground by means of digging carried out by any person inside the shaft with or without the aid of machine tools.
8	Paving Block Layer	To cover or lay (a road, walk, etc.) with concrete, stones, bricks, tiles or wood so as to make a firm, level surface.
9	Plant & Equipment Operator (Load Shifting)	To operate excavators to demolish, dismantle and remove buildings or structures, or any part thereof.
10	Construction Goods Vehicle Driver	To drive vehicles to transport construction materials, building debris or excavated materials within, into or out of construction sites.
11	Cement Sand Mortar Worker	To mix cement and sand for create mortar and place it in different structures; to carry out curing, leveling and smoothening.
12	Demolition Worker	Demolition workers tear down anything from high-rise apartment buildings to bridges or factories, includes blasting (use of explosives), and wrecking (use of machinery and equipment).
13	Metal-steel Worker	To fit, assemble, weld and forge metal and steel parts; to install non-structural metalwork; to operate metal-working machines. To cut or join structural steel sections, steel water mains and steel gas mains by electric arc, oxy-acetylene flame, or other welding processes.
14	Curtain Wall and Glass Panes Installer	To measure, cut and fix glass panes with silicone plastic or beads; to grind or round edges of glass panes.
15	Painter & Decorator	To prepare surfaces, fittings and fixtures of buildings and other structures for painting and decorating.
16	Welder	Specializes in fusing materials together. The materials to be joined can be metals (such as steel, aluminum, brass, stainless steel etc.) or varieties of plastic or polymer.
17	Asbestos Abatement Worker	To remove huge amounts of asbestos materials from industrial buildings, residential complex, plants, and factories. To soften asbestos, the workers spray chemicals to temper the materials.

18	Marble Worker	To set out, measure, cut and set marble slabs, granite slabs or similar stones on walls, floors, or other surfaces; to grind and polish marble, granite or similar stones.
19	Window Frame Installer	To combine and install windows frame of different materials.
20	Prestressing Operative	To introduce internal stresses into (as a structural beam) to counteract the stresses that will result from applied load (as in incorporating cables under tension in concrete)
21	Floor Layer	To prepare or fit the floor base and sometimes install the coverings.
22	Rigger / Metal Formwork Erector	To set up lifting apparatus and equipment for lifting and lowering of materials; to fix and dismantle large panel metal formwork.
23	Asphalter (Road Construction)	To mix, place and compact bituminous materials using vibrating machines; to level and smoothen bituminous materials according to specified level marks.
24	Construction Plant Mechanic [or Fitter]	To fit, assemble, erect, install, maintain and repair mechanical plants and equipment, including emergency generators.
25	Diver (construction work)	To perform under-water operations related to inspection, construction and repair of structures and demolition; to prepare reports on all the foregoing operations.
26	Electrical Fitter (incl. Electrician)	To fit, assemble, install, test, commission, maintain and repair electrical systems and equipment.
27	Electronic Equipment Mechanic	Electronics technicians help design, develop, test, manufacture, install, and repair electrical and electronic equipment. They may be employed in product evaluation and testing, using measuring and diagnostic devices to adjust, test, and repair equipment.
28	Refrigeration / AC / Ventilation Mechanic	To research into electrical and mechanical engineering problems related to refrigeration/air-conditioning/ventilation systems.
29	Fire Service Mechanic	To perform technical tasks, either independently or under the direction of a qualified engineer, contributory to design, development, manufacture, installation, operation, maintenance and repair of fire services systems, equipment and fire extinguishers.
30	Lift and Escalator Mechanic	To install, adjust, maintain and repair lifts.
31	Tunnel Worker	To operate one or more types of plant and equipment for construction work inside tunnels.
32	Marine Construction Plant Operator (Lifting)	To operate one or more types of plant and equipment for construction work at sea including derrick, boom-grab bucket and boom-hook.
33	Track worker	To lay and maintain track works for railways or other vehicles.
34	Piling Operative Worker	To set up piling rigs for driven or bored piles works, with basic knowledge of method, hand signals and geology related to piling.
35	Blasting Worker	To forcibly propelling a stream of abrasive material against a surface under high pressure to smooth a rough surface, shape a surface, or remove surface contaminants.
36	Waterproofing Worker	To protect structural integrity by making the building waterproofed.
37	Gas Installer	To install, commission, maintain and repair domestic and non-domestic gas appliances, gas utilization systems, and gas flow controls and meters connected to gas cylinders or gas supply points.

3.3 ORGANIZATION OF THE BENCHMARKING

The research was conducted by a structured questionnaire that was sent to different companies, departments and organizations through Europe, related to the construction. Nearby countries with similar culture, that we can assume that the construction habitues will be similar and the results through benchmarking have less variability.

In order to make a comparative study of a similar nature conducted in Hong Kong by some colleagues , the chosen operations are based on the Construction Industry Council of Hong Kong.

There are 37 construction trades in the construction industry, as shown in Table 2.

Table 2. List of Construction Trades

1	Woodworker	20	Prestressing Operative
2	Hand-dug Caisson Worker	21	Curtain Wall and Glass Panes Installer
3	Leveler	22	Diver
4	Piling Operative	23	Floor Layer
5	Waterproofing Worker	24	Track worker
6	Drain and Pipe Layer	25	Tunnel Worker
7	Paving Block Layer	26	Plant and Equipment Operator
8	Cement Sand Mortar Worker	27	Bar Bender and Fixer
9	Demolition Worker	28	Painter and Decorator
10	Metal-steel Worker	29	Asphalter
11	Construction Goods Vehicle Driver	30	Blasting Worker
12	Rigger/Metal Formwork Erector	31	Lift and Escalator Mechanic
13	Marine Construction Plant Operator	32	Refrigeration / Air-conditioning / Ventilation Mechanic
14	Asbestos Abatement Worker	33	Fire Service Mechanic
15	Welder	34	Gas Installer
16	Concrete and Grouting Worker	35	Electrician
17	Marble Worker	36	Electronic Equipment Mechanic
18	Window Frame Installer	37	Plant and Equipment Mechanic
19	Scaffolder		

For the respondents' convenience, we create both online soft questionnaire survey and hard copy questionnaire survey in word format (link: https://ust.az1.qualtrics.com/jfe/form/SV_6KEl7HdQgpPsjJ3). Respondents can use both ways to do the survey.

In this questionnaire survey, we asked the respondents to rate the criticality of construction trades after completion the background information. In addition, we have analyzed the level of automation and shortage level of the identified critical construction trades. For building projects (e.g., public housing, private residential and office building projects) and infrastructure projects (e.g., railway and highway projects, bridges and tunnels), we ask about the following aspects:

(1) The relative criticality of each construction trade (“1” – Not Critical, “2” – Fairly Critical, “3” – Critical, “4” – Very Critical, “5” – Extremely Critical) in terms of: (i) percentage of the trade labor cost as of the total project labor cost, (ii) impact of the trade on the project construction time, and (iii) shortage of trade labor supply;

(2) Rate the current level of automation of each construction trade (“1” – Very Low, “2” – Low, “3” – Normal, “4” – High, “5” – Very High).

The survey has been included in appendix 1.

3.4 BACKGROUND RESPONSES

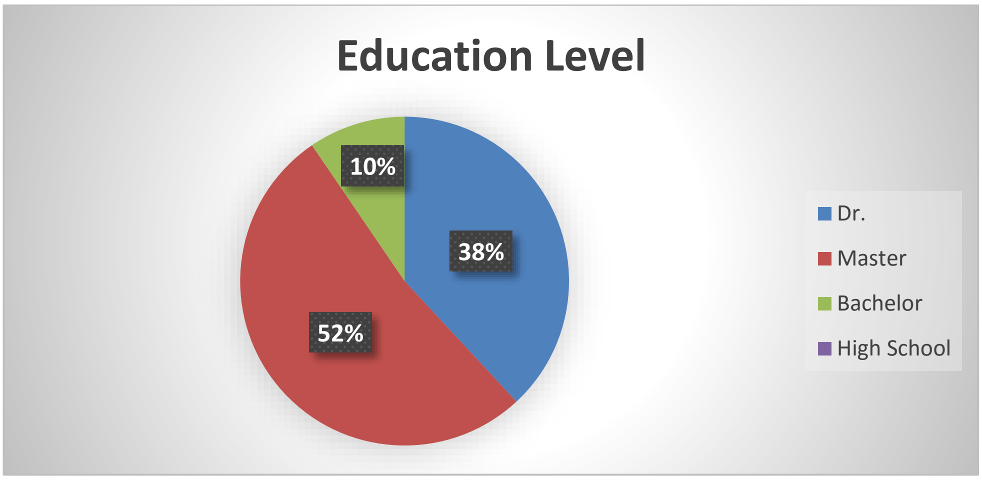
Because of lack of time to send the survey, collect the results, presence in selected countries and the difficulty of the survey, responses have not been as numerous as expected.

Twenty-one respondents returned complete questionnaires. Most of the respondents are from organizations with rich experience. Based on our site web page, 65 questionnaires were started, but after the analysis for see the validity of the answers and respondents, just 6 of them were valid. Most of them were complete just in a 25%, other were from different countries and others with invalid an background. In totally, 15 questionnaires were returned after completion the hard copy word version, and the other 6 through the survey web.

Analyzing the history of the responses obtained through benchmarking; we highlight the following:

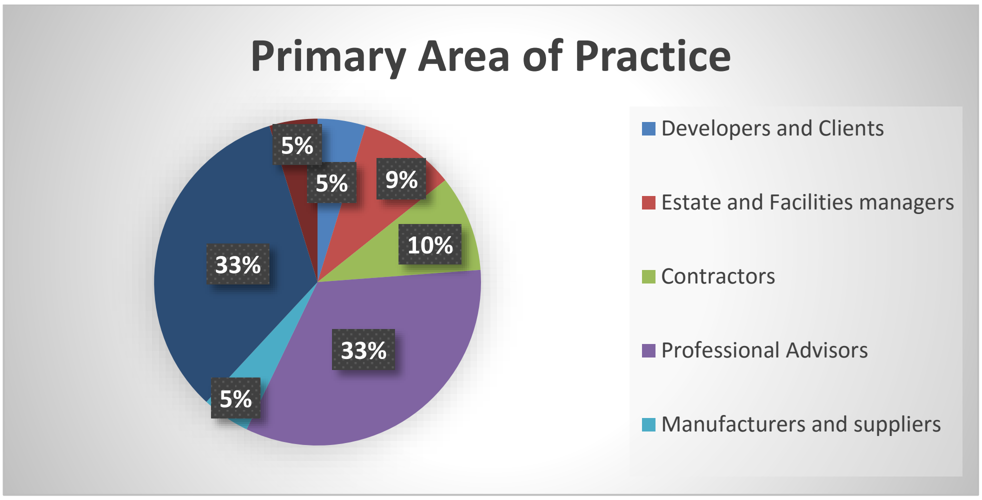
i. More than half of respondents (52%) have a corresponding master education level and 38% are doctors. Only 10% of the respondents have just a bachelor education level and any of them have a high school education.

Figure 4. Background responses – Education Level



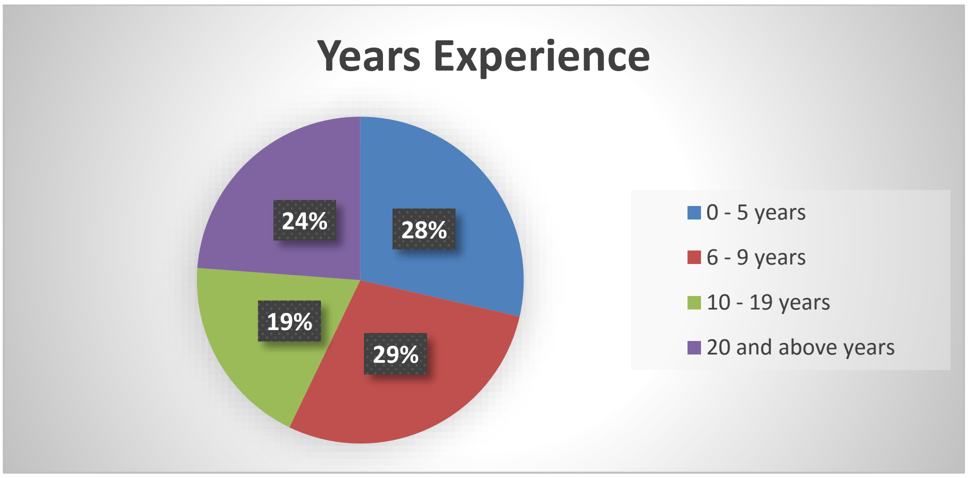
ii. The two major primary area of practice of respondents, with 33% each, have been professional advisors and universities and professional bodies.

Figure 5. Background responses – Primary Area of Practrice



iii. 43% of the results obtained correspond to very experienced people (24%, 20 years and above; 19% between 10 and 19 years) and 29% just to experienced people.

Figure 6. Background responses – Years Experience



Based on the results corresponding to the previous background, we proceed to identify the most critical construction trades.

3.5 IDENTIFYING 10 MOST CRITICAL CONSTRUCTION TRADES

Different construction trades work for different construction activities. A construction trade is considered more critical if it takes a higher percentage of the total project labor cost and has more impact on the project construction time.

In order to determine the ten most critical construction trades respectively for building projects and infrastructure projects in Europe, we calculate the average of each trade and the relative importance index (RII) and get the preliminary result as follows. (For more details related to the used formulas see chapter 2).

i. $\boldsymbol{RII = \frac{\sum W}{A*N}}$

ii. $\boldsymbol{Criticality\ Rank = \frac{Construction\ Time\ Average + Labor\ Cost\ Average}{2}}$

In order to understand the criticality of each construction trade, we define the two following terms as follows:

- Construction time: is the total time needed for a construction trade to be carried out in all its aspects from start to finish during the construction phase.
- Labor cost: it is part of the construction costs (cost of materials, labor cost and equipment cost). Is a number of employee wages and benefits, and can be broken into direct and indirect costs. Unit labor cost is a useful measure of productivity.

Infrastructure Criticality Rank Project

Table 3. Infrastructure Criticality Rank Project

Criticality Rank	Trade	**RII**	Labor Cost Average	Construction Time Average	**Total Cost Average**
1	Tunnel Worker	**0.755**	3.80	3.75	**3.78**
2	Prestressing Operative	**0.714**	3.86	3.29	**3.57**
3	Asphalter (Road Construction)	**0.697**	3.43	3.55	**3.49**
4	Concrete and Grouting Worker	**0.685**	3.43	3.43	**3.43**
5	Drain and Pipe Layer	**0.681**	3.24	3.57	**3.40**
6	Fire Service Mechanic	**0.675**	3.40	3.35	**3.38**
7	Metal-steel Worker	**0.657**	3.76	2.81	**3.29**
8	Marine Construction Plant Operator (Lifting)	**0.645**	3.55	2.90	**3.23**
9	Paving Block Layer	**0.639**	3.15	3.24	**3.20**
10	Welder	**0.638**	3.24	3.14	**3.19**
11	Asbestos Abatement Worker	**0.624**	2.95	3.29	**3.12**
12	Rigger/Metal Formwork Erector	**0.604**	3.24	2.80	**3.02**
13	Trackworker	**0.604**	2.67	3.40	**3.02**
14	Electronic Equipment Mechanic	**0.595**	3.35	2.60	**2.98**
15	Piling Operative	**0.590**	3.33	2.57	**2.95**
16	Electrician	**0.580**	2.80	3.00	**2.90**
17	Gas Installer	**0.560**	2.90	2.70	**2.80**
18	Demolition Worker	**0.557**	2.38	3.19	**2.79**
19	Cement Sand Mortar Worker	**0.552**	2.76	2.76	**2.76**
20	Plant and Equipment Operator	**0.546**	1.90	1.80	**2.73**
21	Lift and Escalator Mechanic	**0.530**	2.65	2.65	**2.65**
22	Leveller	**0.528**	2.76	2.52	**2.64**
23	Refrigeration/Air-conditioning/Ventilation Mechanic	**0.505**	2.50	2.55	**2.53**
24	Blasting Worker	**0.500**	2.70	2.30	**2.50**
25	Waterproofing Worker	**0.495**	2.38	2.57	**2.48**
26	Diver (construction work)	**0.490**	2.24	2.67	**2.45**
27	Floor Layer	**0.466**	2.33	2.33	**2.33**
28	Curtain Wall and Glass Panes Installer	**0.461**	2.33	2.29	**2.31**
29	Hand-dug Caisson Worker	**0.452**	1.81	2.71	**2.26**
30	Marble Worker	**0.414**	2.00	2.14	**2.07**
31	Woodworker	**0.400**	2.33	1.67	**2.00**
32	Bar Bender and Fixer	**0.400**	2.29	1.71	**2.00**
33	Painter and Decorator	**0.400**	2.24	1.76	**2.00**
34	Plant and Equipment Mechanic	**0.370**	1.90	1.80	**1.85**
35	Scaffolder	**0.347**	1.62	1.86	**1.74**
36	Construction Goods Vehicle Driver	**0.319**	1.48	1.71	**1.60**
37	Window Frame Installer	**0.304**	1.48	1.57	**1.52**

The 10 major construction trades are determined by a range of criticality between 0.755 and 0.638 according to the RII; this translates into a range of 3.78 and 3.19 respectively, on the scale used for our respondents to assess their criticality.

The average of the 10 most important operation is 0.678 (RII), corresponding to a 3.39 under a total of 5. In this rating, the labor cost aspect has resulted in more importance compared to the construction time, with an average of 3.48 (0.697, RII) and 3.3 (0.660, RII) respectively for the 10 most critical trades.

Related to the infrastructure construction trades general rank, the overall average has resulted of 2.7 (0.540, RII), corresponding to an overall average of 2.74 (0.548, RII) for the labor cost and an overall average of 2.67 (0.534, RII) for the construction time. The range between the most important trade (tunnel worker, 3.78) and the less important (window frame installer, 1.52) is 2.26 (0.452, RII).

Building Criticality Rank Project

For the analysis of criticality construction trades for building projects, a few of them do not make sense for such projects, so they have been discarded from the analysis. Such construction trades are the following four: drain and pipe layer; paving block layer; trackworker; and tunnel worker.

Table 4. Building Criticality Rank Project

Criticality Rank	Trade	**RII**	Labor Cost Average	Construction Time Average	**Total Cost Average**
1	Welder	**0.714**	3.62	3.52	**3.57**
2	Electrician	**0.695**	3.45	3.50	**3.48**
3	Prestressing Operative	**0.657**	3.81	2.76	**3.29**
4	Asbestos Abatement Worker	**0.655**	3.00	3.55	**3.28**
5	Piling Operative	**0.642**	3.24	3.19	**3.21**
6	Hand-dug Caisson Worker	**0.619**	3.19	3.00	**3.10**
7	Woodworker	**0.590**	2.52	3.38	**2.95**
8	Metal-steel Worker	**0.585**	3.14	2.71	**2.93**
9	Marble Worker	**0.561**	3.38	2.24	**2.81**
10	Electronic Equipment Mechanic	**0.555**	2.80	2.75	**2.78**
11	Curtain Wall and Glass Panes Installer	**0.552**	2.86	2.67	**2.76**

12	Floor Layer	**0.547**	2.71	2.76	**2.74**
13	Concrete and Grouting Worker	**0.542**	2.43	3.00	**2.71**
14	Refrigeration/Air-conditioning/Ventilation Mechanic	**0.540**	2.55	2.85	**2.70**
15	Fire Service Mechanic	**0.520**	2.75	2.14	**2.60**
16	Diver (construction work)	**0.504**	2.29	2.76	**2.52**
17	Waterproofing Worker	**0.504**	2.38	2.67	**2.52**
18	Blasting Worker	**0.492**	2.29	2.65	**2.46**
19	Demolition Worker	**0.471**	2.38	2.33	**2.36**
20	Cement Sand Mortar Worker	**0.471**	2.29	2.43	**2.36**
21	Painter and Decorator	**0.471**	2.38	2.33	**2.36**
22	Asphalter (Road Construction)	**0.457**	2.29	2.29	**2.29**
23	Marine Construction Plant Operator (Lifting)	**0.455**	2.80	1.75	**2.28**
24	Plant and Equipment Mechanic	**0.440**	2.15	2.25	**2.20**
25	Lift and Escalator Mechanic	**0.430**	1.85	2.45	**2.15**
26	Scaffolder	**0.428**	2.14	2.14	**2.14**
27	Leveller	**0.419**	1.71	2.48	**2.10**
28	Gas Installer	**0.415**	1.70	2.45	**2.08**
29	Rigger/Metal Formwork Erector	**0.414**	2.29	1.86	**2.07**
30	Plant and Equipment Operator	**0.405**	1.75	2.25	**2.03**
31	Bar Bender and Fixer	**0.347**	1.81	1.67	**1.74**
32	Window Frame Installer	**0.338**	1.52	1.86	**1.69**
33	Construction Goods Vehicle Driver	**0.314**	1.48	1.67	**1.57**
34	Drain and Pipe Layer	**-**	-	-	**-**
35	Paving Block Layer	**-**	-	-	**-**
36	Trackworker	**-**	-	-	**-**
37	Tunnel Worker	**-**	-	-	**-**

The 10 major construction trades are determined by a range of criticality between 0.714 and 0.555 according to the RII; this translates into a range of 3.57 and 2.78 respectively, on the scale used for our respondents to assess their criticality.

The average of the 10 most important operation is 0.628 (RII), corresponding to a 3.14 under a total of 5. In this rating, the labor cost aspect has resulted in more importance compared to the construction time, the same as infrastructure projects, with an average of 3.21 (0.643, RII) and 3.06 (0.612, RII) respectively for the 10 most critical trades.

Related to the infrastructure construction trades general rank, the overall average has resulted of 2.54 (0.508, RII), corresponding to an overall average of 2.51 (0.502, RII) for the labor cost and an overall average of 2.57 (0.514, RII) for the construction time. The range between the most important trade (welder, 3.57) and the less important (construction goods vehicle driver, 1.57) is 2 (0.40, RII).

Comparison between Building and Infrastructure Criticality Rank Project

Through the above analysis we get the following:

i. For both 10 major construction trades for infrastructure and building projects, the labor cost aspect is more important than the construction time.

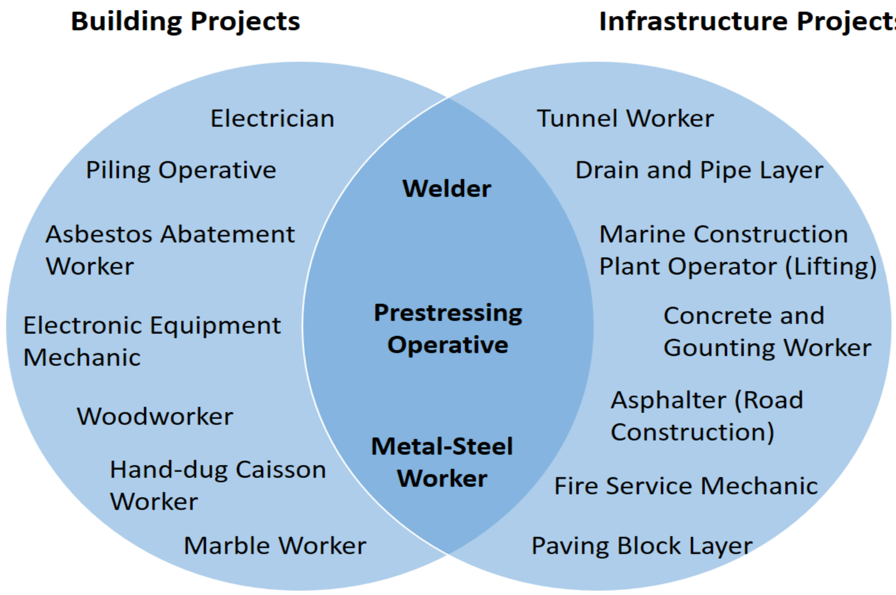
ii. The standard deviation for both ranks is small, near 0.5 (average scale), so the degree of data dispersion is low and the average is a reliable data.

iii. The range for both ranks is similar, near 2. That means the highest and lowest construction trade criticality for both projects is similar.

iv. The average for the 10 major construction trades in infrastructure projects is highest than the 10 major construction trades for building construction trades. The same goes for all the ranking of operations on both projects. This translates the reality, cause infrastructure projects are often more expensive than building projects.

v. Of the 10 critical construction trades for both projects, only 3 of them are common due the variety of type of projects.

Figure 7. List of the 10 major construction trades for infrastructure and building projects



3.6 ADDITIONAL RESULTS

3.6.1 – Labor Shortage Level

A labor shortage is an economic condition in which there are insufficient qualified candidates (employees) to fill the market-place demands for employment at any price. For the construction industry, many trades associated face the issue of skill and manpower shortage.

Many specialty trade workers have switched industries and professional workers have switched countries entirely; a common aspect in Europe due the “absence” of borders for Europeans. The demand for a temporary construction workforce from a contractor is increasing as their requirements for specific needs are limited to specific project stages.

With an existing labor shortage, some solutions have to be taken. According to the newspaper “Construction Business Owner”, one solution that can be envisaged is the apprenticeships. Set up an arrangement to provide apprenticeship program for civil engineering for those most critical construction trades.

In order to improve the productivity, the labor shortage of each operation need to be calculated, for identify the critical construction trades based in this aspect.

i. Infrastructure Project

The 10 major labor shortage trades are determined by a range of criticality between 0.73 and 0.55 according to the RII; this translates into a range of 3.65 and 2.75 respectively, on the scale used for our respondents to assess their criticality. The average of the 10 most critical trades is 0.653 (RII), corresponding to a 3.27 under a total of 5.

Related to the labor shoratge criticality for infrastructure construction trades general rank, the overall average has resulted of 2.57 (0.513, RII). The range between the most important trade (tunnel worker, 3.65) and the less important (construction goods vehicle driver, 1.52) is 2.13 (0.426, RII).

Table 5. Labor shortage criticality for infrastructure construction trades

Criticality Rank	Trade	**RII**	**Labor Shortage Average**
1	Tunnel Worker	**0.730**	**3.65**
2	Prestressing Operative	**0.695**	**3.48**
3	Metal-steel Worker	**0.676**	**3.38**
4	Concrete and Grouting Worker	**0.676**	**3.38**
5	Blasting Worker	**0.670**	**3.35**
6	Piling Operative	**0.647**	**3.24**
7	Trackworker	**0.647**	**3.24**
8	Diver (construction work)	**0.638**	**3.19**
9	Demolition Worker	**0.600**	**3.00**
10	Plant and Equipment Operator	**0.550**	**2.75**
11	Drain and Pipe Layer	**0.533**	**2.67**
12	Curtain Wall and Glass Panes Installer	**0.533**	**2.67**
13	Cement Sand Mortar Worker	**0.523**	**2.62**
14	Asphalter (Road Construction)	**0.523**	**2.62**
15	Refrigeration/Air-conditioning/Ventilation Mechanic	**0.520**	**2.60**
16	Marine Construction Plant Operator (Lifting)	**0.510**	**2.55**
17	Asbestos Abatement Worker	**0.510**	**2.55**
18	Woodworker	**0.504**	**2.52**
19	Leveller	**0.504**	**2.52**
20	Floor Layer	**0.495**	**2.48**
21	Paving Block Layer	**0.490**	**2.45**
22	Lift and Escalator Mechanic	**0.490**	**2.45**
23	Electrician	**0.490**	**2.45**
24	Plant and Equipment Mechanic	**0.480**	**2.40**
25	Waterproofing Worker	**0.476**	**2.38**
26	Rigger/Metal Formwork Erector	**0.476**	**2.38**
27	Welder	**0.476**	**2.38**
28	Electronic Equipment Mechanic	**0.470**	**2.35**
29	Hand-dug Caisson Worker	**0.438**	**2.19**
30	Scaffolder	**0.438**	**2.19**
31	Marble Worker	**0.428**	**2.14**
32	Painter and Decorator	**0.400**	**2.00**
33	Gas Installer	**0.390**	**1.95**
34	Fire Service Mechanic	**0.370**	**1.85**
35	Window Frame Installer	**0.360**	**1.80**
36	Bar Bender and Fixer	**0.333**	**1.67**
37	Construction Goods Vehicle Driver	**0.304**	**1.52**

ii. Building Project

Table 6. Labor shortage criticality for building construction trades

Criticality Rank	Trade	RII	Labor Shortage Average
1	Prestressing Operative	0.733	3.67
2	Marine Construction Plant Operator (Lifting)	0.720	3.60
3	Woodworker	0.704	3.52
4	Blasting Worker	0.690	3.45
5	Welder	0.657	3.29
6	Piling Operative	0.638	3.19
7	Asbestos Abatement Worker	0.570	2.85
8	Marble Worker	0.561	2.81
9	Electrician	0.560	2.80
10	Diver (construction work)	0.552	2.76
11	Metal-steel Worker	0.552	2.76
12	Rigger/Metal Formwork Erector	0.542	2.71
13	Hand-dug Caisson Worker	0.523	2.62
14	Asphalter (Road Construction)	0.523	2.62
15	Refrigeration/Air-conditioning/Ventilation Mechanic	0.520	2.60
16	Electronic Equipment Mechanic	0.520	2.60
17	Curtain Wall and Glass Panes Installer	0.504	2.52
18	Gas Installer	0.490	2.45
19	Lift and Escalator Mechanic	0.480	2.40
20	Plant and Equipment Mechanic	0.480	2.40
21	Concrete and Grouting Worker	0.476	2.38
22	Window Frame Installer	0.476	2.38
23	Floor Layer	0.476	2.38
24	Fire Service Mechanic	0.460	2.30
25	Leveller	0.447	2.24
26	Waterproofing Worker	0.447	2.24
27	Demolition Worker	0.400	2.00
28	Scaffolder	0.400	2.00
29	Painter and Decorator	0.400	2.00
30	Plant and Equipment Operator	0.380	1.90
31	Cement Sand Mortar Worker	0.361	1.81
32	Bar Bender and Fixer	0.323	1.62
33	Construction Goods Vehicle Driver	0.247	1.24
34	Drain and Pipe Layer	-	-
35	Paving Block Layer	-	-
36	Trackworker	-	-
37	Tunnel Worker	-	-

The 10 major labor shortage trades are determined by a range of criticality between 0.733 and 0.552 according to the RII; this translates into a range of 3.67 and 2.76 respectively, on the scale used for our respondents to assess their criticality. The average of the 10 most critical trades is 0.638 (RII), corresponding to a 3.19 under a total of 5.

Related to the labor shortage criticality for building construction trades general rank, the overall average has resulted of 2.55 (0.509, RII). The range between the most important trade (prestressing operative, 3.67) and the less important (construction goods vehicle driver, 1.24) is 2.43 (0.486,RII).

iii. Results discussion

Through the above analysis we get the following:

i. The standard deviation for both ranks is small, near 0.5 (average scale), so the degree of data dispersion is low and the average is a reliable data.

ii. The average for the 10 major labor shortage construction trades in infrastructure projects is highest than the 10 major for building construction trades. The same goes for all the ranking of operations on both projects.

iii. Of the 10 critical labor shortage construction trades for both projects, four of them are common: prestressing operative, blasting worker, piling operative and diver (construction work).

iv. For both types of project, the two lowest labor shortage construction trades are the same, bar bender and fixer and construction goods vehicle driver.

3.6.2 – Automation Level

Automation in construction is an international journal for the publication of original research papers. The journal publishes refereed material on all aspects pertaining to the use of Information Technologies in Design, Engineering, Construction Technologies, and Maintenance and Management of Constructed Facilities.

In our research, we have focused solely on obtaining the level of automation of the various construction trades, in order to see those that need further improvements to improve productivity.

According to CII (2008), potential labor productivity improvements associated with the use of technologies in construction range from 30-40 percent.

i. Infrastructure Projects

Table 7. Automation level for infrastructure construction trades

Criticality Rank	Trade	RII	Automation Level Average
1	Prestressing Operative	0.866	4.33
2	Metal-steel Worker	0.800	4.00
3	Asphalter (Road Construction)	0.761	3.81
4	Tunnel Worker	0.760	3.80
5	Bar Bender and Fixer	0.752	3.76
6	Plant and Equipment Operator	0.720	3.60
7	Concrete and Grouting Worker	0.657	3.29
8	Trackworker	0.657	3.29
9	Leveller	0.638	3.19
10	Blasting Worker	0.630	3.15
11	Welder	0.600	3.00
12	Drain and Pipe Layer	0.561	2.81
13	Woodworker	0.542	2.71
14	Electrician	0.530	2.65
15	Waterproofing Worker	0.514	2.57
16	Paving Block Layer	0.510	2.55
17	Fire Service Mechanic	0.510	2.55
18	Electronic Equipment Mechanic	0.510	2.55
19	Curtain Wall and Glass Panes Installer	0.504	2.52
20	Floor Layer	0.504	2.52
21	Piling Operative	0.485	2.43
22	Cement Sand Mortar Worker	0.485	2.43
23	Rigger/Metal Formwork Erector	0.485	2.43
24	Diver (construction work)	0.485	2.43
25	Lift and Escalator Mechanic	0.480	2.40
26	Gas Installer	0.480	2.40
27	Plant and Equipment Mechanic	0.480	2.40
28	Painter and Decorator	0.476	2.38
29	Refrigeration/Air-conditioning/Ventilation Mechanic	0.470	2.35
30	Demolition Worker	0.457	2.29
31	Hand-dug Caisson Worker	0.400	2.00
32	Marble Worker	0.371	1.86
33	Scaffolder	0.371	1.86
34	Marine Construction Plant Operator (Lifting)	0.370	1.85
35	Window Frame Installer	0.342	1.71
36	Asbestos Abatement Worker	0.340	1.70
37	Construction Goods Vehicle Driver	0.295	1.48

The 10 major automation trades are determined by a range of criticality between 0.866 (prestressing operative) and 0.630 (blasting worker) according to the RII; this translates into a range of 4.33 and 3.15 respectively, on the scale used for our respondents to assess their criticality. The average of the 10 most automated trades is 0.724 (RII), corresponding to a 3.62 under a total of 5.

Related to the automation level for building construction trades general rank, the overall average has resulted of 2.68 (0.536, RII). The range between the most automated trade (prestressing operative, 4.33) and the less automated (construction goods vehicle driver, 1.48) is 2.85 (0.570, RII).

ii. Building Projects

Table 8. Automation level for building construction trades

Criticality Rank	Trade	RII	Automation Level Average
1	Prestressing Operative	**0.838**	**4.19**
2	Leveller	**0.752**	**3.76**
3	Piling Operative	**0.742**	**3.71**
4	Bar Bender and Fixer	**0.714**	**3.57**
5	Welder	**0.676**	**3.38**
6	Fire Service Mechanic	**0.676**	**3.38**
7	Demolition Worker	**0.571**	**2.86**
8	Plant and Equipment Operator	**0.570**	**2.85**
9	Blasting Worker	**0.570**	**2.85**
10	Cement Sand Mortar Worker	**0.561**	**2.81**
11	Aspalter (Road construction)	**0.560**	**2.80**
12	Electrician	**0.550**	**2.75**
13	Metal-steel Worker	**0.542**	**2.71**
14	Rigger/Metal Formwork Erector	**0.514**	**2.57**
15	Refrigeration/Air-conditioning/Ventilation Mechanic	**0.510**	**2.55**
16	Lift and Escalator Mechanic	**0.500**	**2.50**
17	Woodworker	**0.495**	**2.48**
18	Concrete and Grouting Worker	**0.495**	**2.48**
19	Electronic Equipment Mechanic	**0.490**	**2.45**
20	Diver (construction work)	**0.466**	**2.33**
21	Asbestos Abatement Worker	**0.460**	**2.30**
22	Waterproofing Worker	**0.457**	**2.29**
23	Curtain Wall and Glass Panes Installer	**0.457**	**2.29**
24	Plant and Equipment Mechanic	**0.450**	**2.25**
25	Floor Layer	**0.447**	**2.24**
26	Marine Construction Plant Operator (Lifting)	**0.420**	**2.10**
27	Window Frame Installer	**0.371**	**1.86**
28	Gas Installer	**0.370**	**1.85**

29	Hand-dug Caisson Worker	**0.352**	**1.76**
30	Scaffolder	**0.352**	**1.76**
31	Painter and Decorator	**0.352**	**1.76**
32	Marble Worker	**0.323**	**1.62**
33	Construction Goods Vehicle Driver	**0.295**	**1.48**
34	Drain and Pipe Layer	**-**	**-**
35	Paving Block Layer	**-**	**-**
36	Trackworker	**-**	**-**
37	Tunnel Worker	**-**	**-**

The 10 major automation trades are determined by a range of criticality between 0.838 (prestressing operative) and 0.561 (cement and sand worker) according to the RII; this translates into a range of 4.19 and 2.81 respectively, on the scale used for our respondents to assess their criticality. The average of the 10 most automated trades is 0.667 (RII), corresponding to a 3.34 under a total of 5.

Related to the automation level for building construction trades general rank, the overall average has resulted of 2.56 (0.512,RII). The range between the most automated trade (prestressing operative, 4.19) and the less automated (construction goods vehicle driver, 1.48) is 2.71 (0.542, RII).

iii. Results discussion

Through the above analysis we get the following:

i. The standard deviation for both ranks is small, near 0.5 (average scale), so the degree of data dispersion is low and the average is a reliable data.

ii. The average for the 10 major automated construction trades in infrastructure projects is highest than the 10 major for building construction trades. The same goes for all the ranking of operations on both projects.

iii. Of the 10 most automated construction trades for both projects, four of them are common: prestressing operative, blasting worker, leveller and bar bender and fixer.

iv. For both types of project, two lowest automated construction trades are construction goods vehicle driver, and the highest is prestressing operative.

3.7 SUMMARY RESULTS

By the previous analyses shown before to see the criticality of each construction trade related to their cost (construction time cost and labor cost) and additional classifications such as the automation level and the level shortage of them, we can obtain some conclusions.

All the critical construction trades take a high percentage of the total cost of the project, so all of them needs to be improved to save the most money possible. Thus needing a better improvement are these with a high labor shortage and a low automation level.

The criticality rank for **Building** Project:

Table 9. List of Critical Building Construction Trades in Europe

Criticality Rank	Trade	Labor Shortage Internal Rank	Labor Shortage Overall Rank	Automation Internal Rank	Automation Overall Rank
1	**Welder**	3	5	3	6
2	Electrician	7	12	4	13
3	**Prestressing Operative**	1	1	1	1
4	Asbestos Abatement Worker	5	9	8	24
5	Piling Operative	4	6	2	3
6	Hand-dug Caisson Worker	9	16	9	32
7	Woodworker	2	3	6	20
8	**Metal-steel Worker**	8	14	5	15
9	Marble Worker	6	11	10	36
10	Electronic Equipment Mechanic	10	19	7	22

For building projects, table 9 illustrate the following:

i. Five critical construction trades have a high automation level. In order to improve the labor productivity, the automation level of the lowest trades has to be improved. Five critical construction trades need to improve their automation, being these: Asbestos abatement worker (24th overall rank); hand-dug caisson worker (32nd overall rank); woodworker (20th overall rank); marble worker (36th overall rank); and, electronic equipment mechanic (22th overall rank).

ii. Related to the labor shortage, all of the previous trades needs to be improved because of they low labor shortage overall rank. All of them are on the first 50% of the overall rank, except the electronic equipment mechanic.

The criticality rank for **Infrastructure** Project:

Table 10. List of Critical Infrastructure Construction Trades in Europe

Criticality Rank	Trade	Labor Shortage Internal Rank	Labor Shortage Overll Rank	Automation Internal Rank	Automation Overall Rank
1	Tunnel Worker	1	1	4	4
2	**Prestressing Operative**	2	2	1	1
3	Asphalter (Road Construction)	6	14	3	3
4	Concrete and Grounting Worker	4	4	5	7
5	Drain and Pipe Layer	5	11	7	12
6	Fire Service Mechanic	10	34	9	17
7	**Metal-steel Worker**	3	3	2	2
8	Marine Construction Plant Operator (Lifting)	7	16	10	34
9	Paving Block Layer	8	21	8	16
10	**Welder**	10	27	7	11

Note: The trades in bold are the same critical trades both in Building Project and Infrastructure Project.

For building projects, table 9 illustrate the following:

i. Most of the construction trades have a high automation level. Nine (9) of them are ranked in the 50% more automated trades. In order to improve the labor productivity, the automation level of the lowest trades has to be improved. One critical construction trade needs to improve his automation, being marine construction plant operator (lifting) (34^{th} overall rank);

ii. Related to the labor shortage, all of the previous trades needs to be improved because of they low labor shortage overall rank, they are on the first 50% of the overall rank, except three of them. Fire service mechanic (34^{th} overall rank); paving block layer (21^{st} overall rank); and, welder (27^{th} overall rank).

CHAPTER 4. FACTORS AFFECTING THE CRITICAL TRADES

4.1 CASE STUDY

This chapter aims to improve the construction productivity in Europe by establishing productivity questionnaires at the factors trade level through the continent with the following objectives:

i. To determine ten most critical construction factors affecting the productivity of a list of fifteen (15) critical construction trades previously found for typical types of building and infrastructure projects in Europe;

ii. To determine the weightings importance of the six group of factors containing the previous factors affecting the construction trades productivity;

iii. To determine the previous critical factors in Europe in order to make comparisons with those found in a study by my colleagues in Hong Kong; and

iv. To determine the importance of questionnaire surveys for data collection.

For this chapter, it is important to note that critical trades used for the factors research are those found by my Hong Kong colleagues, for several reasons:

i. The further comparative no sense with different construction trades between their and my questionnaire, because the importance of factors affecting productivity is noted based on these. So the criterion for the notation would have been different; and

ii. The construction trades chosen have been this of Hong Kong before the European because the total responses collected to identify them has been higher in their study, and also, my colleagues will continue the study for further studies related to the Hong Kong case.

Note that the list of the fifteen Hong Kong critical construction trades provided then, ten of them are the same as those found for the European case.

Table 11. List of Hong Kong critical construction trades

1	Bar bender and fixer	9	Plant and equipment operator
2	Concrete and gouting worker	10	Curtain wall and glass panes installer
3	Rigger/metal formwork erector	11	Tunnel worker
4	Woodworker	12	Electrician
5	Welder	13	Prestressing operative
6	Metal-steel worker	14	Blasting worker
7	Scaffolder	15	Cement and sand worker
8	Piling operative		

4.2 FACTORS AFFECTING CONSTRUCTION PRODUCTIVITY

Identification and evaluation of factors affecting labor construction productivity have become a critical issue facing project managers for a long time in order to increase productivity in construction. Understanding critical factors affecting the productivity of both positive and negative can be used to prepare a strategy to reduce inefficiencies and to improve the effectiveness of project performance.

Difficulties on productivity with established values are compounded by the existence of a large number of influencing factors. Everything affects productivity. They are rarely constant, and vary from country to country, from project to Project.

It is desirable to better understand the factors in construction productivity in order to further develop and improve it.

There are numerous factors which have an influence on labor productivity, and can be classified as follow.

i. Changes/errors in the original scope of work and complexity of the work: errors and/or omission in specification and quality requirements; technical specifications unclear; design changes, errors and omissions; design complexity; additions to the original scope of work; errors and/or omissions in construction method; and complexity of construction method.

ii. Poor resource plan and logistics: material delivery problems; material supply problems; unavailability of tools and equipment; improper allocation of tools and equipment; poor equipment maintenance; improper crew size and composition; and constrained construction site.

iii. Schedule changes and compression: schedule acceleration; overtime work; overmanning; multiple shifts; and rescheduling activities.

iv. Morale problems of workforce; fatigue, mental and physical stress of workers; worker absenteeism; worker turnover; worker payment and compensation issues; lack of an incentive scheme and respect for the worker; inconsistent work rules by different managers; and increasing the risk of accidents.

v. Qualification and communication problems; shortage of skilled and experienced workers; unavailability of training and orientation programs for workers; slow decisions of owners or site managers; communication problems between site management and workers; improper coordination between the different trades; and language barriers

vi. External factors: unfavorable economic and financial environment; unfavorable political environment; social and cultural issues; labor shortage; slow government/regulatory approval process; and adverse weather events.

The previous forty (40) factors and six (6) groups to which they belong are explained in the following table :

Table 12. List of factors and group factors affecting construction productivity

No.	Factor	Definition/ description
I. Changes/ errors in the original scope of work and the complexity of the work		***This group of factors is related to existing changes, errors or complexities of the work which has to be done involving specification requirements, design details, construction components, etc.***
1	Errors and/or omission in specifications and quality requirements	Arises when the necessary specifications are erroneous or omitted due to material, design, working method or construction components, etc.
2	Unclear Technical specifications	Arises when the necessary requirements need clarification of the information to be implemented in the work.
3	Design changes, errors and omissions	Arises when any unnecessary changes or incorrect procedures are taken during design process
4	Design complexity	May occur when a design is more difficult than that of many similar type structures. For example, certain design details require more than normal amounts of cutting, shaping and handling.
5	Additions to the original scope of work	Arises when the amount of work, which needs to be done, is increased from the planned amount.
6	Inappropriate construction method	Arises when there is any incorrect procedures and techniques during construction process which might resulted from the misconceptions of the workers.
7	Complexity of construction method	May occur when the procedures and techniques utilized during construction are more difficult than that of many similar types.

II. Poor resource planning and logistics		***This group involves adverse resource management which includes problems with supply and delivery of material, tools and equipment; also, their allocation on the construction site.***
8	Material delivery problems	Is related to improper material logistics due to delivery at an inappropriate time. For example, late deliveries, delivery material out-of-sequence, delivery material out-of-specification, etc.
9	Unavailability of tools and equipment	Is related to improper resource management due to the supply of tools and equipment in inappropriate quantities and quality. For example, shortage of personal protective equipment, unavailability of hand and power tools, poor quality of power tools, etc.
10	Improper allocation of tools and equipment	Is related to erroneous placement and movement of tools and equipment on a construction site. For example, misplaced tools, unnecessary equipment movement, etc.
11	Poor conditions of tools and equipment	Occur when there is a lack of maintenance programs to keep tools and equipment in a functioning state and preview future from unexpected failures.
12	Improper crew size and composition	This factor is related to the crew characteristics, such as balance of qualified workers and ancillary workers; the crew size is not sufficient to complete the activities on time, changing crew member, etc.
13	Overmanning	This refers to miscalculation of number of workers that are supposed to perform one kind of construction work. In other words, the number of workers exceeds the maximum optimal crews.
14	Idle time	This is any unproductive time on the part of the crew due to disruptions.
III. Schedule compression and changes		***Factors in this group appear when the job site management is compelled to compress and/or change the schedule to complete a project on time.***
15	Constrained construction site	This results from lack of space on a construction site for the location of tools and supporting utilities for optimum product flow. For example, lack of suitable rest areas offered to workers on site; size too small and remote storage locations; restricted access.
16	Schedule acceleration	This refers to construction works/ activities that have to be performed in parallel or more construction workloads that needed to be done in shorter amount of time.
17	Overtime work	Arises when the excessive scheduling or total working hours of the workers exceed the standardized normal rule.
18	Reworking	This refers to any additional and non-essential of works during construction process because of lack of supervising.
19	Multiple shifts	May occur when the second shift of workers in the same trade continues work of the first shift.
20	Schedule changes	This refers when workers are instructed to some construction works in sequences ordered but systematically in original plan.
21	Improper coordination between the different trades	This relates to a lack of coordination management between various trades and their improper allocation on a construction site.

IV. Morale problems of workforce		**Factors in this group are related to the results or triggering events which decrease the workers' morale through unpleasant physical and emotional conditions.**
22	Fatigue, mental and physical stress of workers	This relates to a specific response of the body to a stimulus, which disturbs or interferes with the normal physiological and psychological equilibrium causing tiredness.
23	Worker absenteeism	This occurs when workers are absence from the working days due to acceptable reasons as well as their frequency of missing the working days without asking for time-off.
24	Frequent worker turnover	This is related to the number or percentage of workers who leave the organization and are replaced by new employees.
25	Worker payment and compensation issues	Arises due to late and unfair payment and compensation to the workers. For example, payment delays, different pay scales for the same job, etc.
26	Lack of an incentive scheme and respect for workers	This refers to low worker motivation due to lack of positive action by management to encourage workers.
27	Inconsistent rules of different supervision/management people	This occurs due to the contradictory interpretation regulations and principles by managers governing the behavior of workers or procedures.
28	Inadequate safety measures	This relates to poor site conditions which increases the risk of injury. A poor safety culture also affect this factor.
V. Qualification and communication problems		***Factors in this group relate to the shortage of skilled and experienced project participants and lack of proper communication among them.***
29	Shortage of skilled and experienced workers	This relates to a lack of workers with the appropriate education level and experience to perform work with high quality.
30	Lack of training and orientation programs for workers	This refers to a lack of training and orientation programs for improving labor skills.
31	Slow management decisions process	This is caused when the process of making decisions by the owners or site managers is slow. It can be due to a lack of qualifications and experience, complexity of the procedures, extraordinary situations, etc.
32	Poor qualification/ experience of management at different levels	This relates to the inadequate education level or experience of managers to make accurate decisions.
33	Communication problems between site management and workers	Can occur due to misunderstandings between site management and workers or lack of regular meetings.
34	Language barriers	This occurs when workers come from different countries or different areas of the same country (e.g. China, India), having different native languages/dialects and having to use another language for communication.
VI. External factors		***Factors in this group are related to the events, situations and decisions which are beyond to control of the owners, contractors and crews.***
35	Unfavorable economic and financial environment	This relates to the economic and financial environment of a country or a particular region which can affect the viability of the whole construction project and job security of workers. For example, an economic downturn, high currency exchange rates, high taxes and economic restrictions can lead to the infeasibility of a project, its freezing or cancelation, which related to a reduction in the workforce.

36	Unfavorable political environment	This refers to unforeseen situation of government policy on construction projects such as construction practices, guidelines, laws which are adverse.
37	Social and cultural issues	This occurs when any unfavorable conditions of socio-cultural conditions, customs, habits, that impact the character of people in that particular society. As an example, a lack of access to social amenities, a low literacy level, and beliefs can lead to discontent. Discontent in the social and cultural area can lead to civil conflicts or disturbance (strikes, demonstrations).
38	Labor shortage	Occurs when there is an excess demand in the labor market.
39	Slow Government/ Regulatory approval process	Can occur when the process of getting approval to continue a project by Government or Regulatory Bodies is slow.
40	Adverse weather events	This is when unexpected weather condition occurs, such as high/low temperature, strong wind, heavy rain, humidity, or any extreme/concerned weather conditions.

4.3 ORGANIZATION OF THE QUESTIONNAIRE

The research was conducted by a structured questionnaire that was sent to different companies, departments and organizations through Europe, related to the construction. Many of them the same surveyed on the previously benchmarking for finding the critical construction trades.

For the respondents' convenience, we create both online soft questionnaire survey and hard copy questionnaire survey in word format (link: https://ust.az1.qualtrics.com/jfe/form/SV_9EnFZYJWIUzh8rz). Respondents can use both ways to do the survey.

At the beginning of the questionnaire, we explain the background of this survey, the aim of the survey, how to complete and return the questionnaire and to warm them of the confidentiality of their responses. All of this in the first section called “Introduction to the Questionnaire Survey”. After this, we asked the respondents to complete different sections:

i. Section B “Background of Respondents”. In this part, they must complete different aspects related to their profile, some of which are optional. The different aspects are: name; organization; email address; job/position; primary area of practice; years of experience and education level.

ii. Section C “Weightings of the six groups of factors”. They have to assign a percentage weighting (%) to each of the six groups such that the sum of the weightings of the six group is 100% in the following table.

Table 13. List of group factors affecting construction producitivy

No.	Factor Group	Weightings
1	Changes/errors in the original scope of work and the complexity of the work	
2	Poor resource plan and logistics	
3	Schedule changes and compression	
4	Morale problems of workforce	
5	Qualification and communication problems	
6	External factors	
Total		**100%**

iii. Section D “Relative importance of the 40 Factors”. Respondents have to rate the relative importance of each of the 40 factors in terms of their individual impact on the productivity of the 15 critical construction trades shown before on a scale of 0 to 5 (“0” – Not applicable, “1” – Low significant, “2” – Fairly significant, “3” – Significant, “4” – Very significant, “5” – Extremely significant). These factors have been separated in the survey according to the above groups to which belongs.

Table 14. List of factors affecting construction producitivy

1	Erros/omissions in specifications and quality requirements	21	Improper coordination between diferent construction trades
2	Unclear technical specifications	22	Inconsistent rules of different supervision/ management people
3	Design changes, errors and omissions	23	Fatigue, mental and physical strees of workers
4	Design complexity	24	Worker absenteeism
5	Additions to the original scope of work	25	Frequent worker turnover
6	Inappropriate construction method	26	Worker payment and compensation issues
7	Complexity of construction method	27	Lack of incentives and respect for workers
8	Material delivery problems	28	Inadequate safety measures

9	Unavailability of tools and equipment	29	Shortage of skilled/experienced workers
10	Improper allocation of tools and equipment	30	Poor qualification/experience of management at different levels
11	Poor conditions of tools and equipment	31	Lack of training/orientation program for workers
12	Improper crew size and composition	32	Slow management decision process
13	Overmanning	33	Communication problems between management and workers
14	Idle time	34	Language barriers
15	Constrained construction site	35	Unfavorable economic and financial conditions
16	Schedule acceleration	36	Unfavorable political environment
17	Overtime work	37	Social injustice and cultural conflicts
18	Rework	38	Labor shortage
19	Multiple shifts	39	Slow government approval process
20	Schedule changes	40	Adverse weather

The survey has been included in appendix 2.

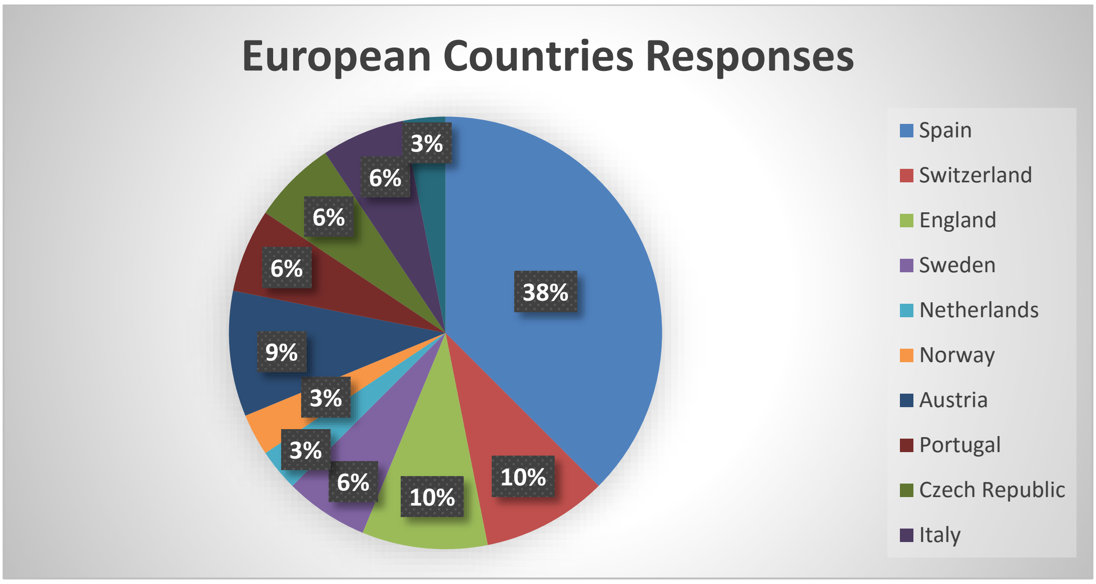
4.4 BACKGROUND RESPONSES

This survey has been more successful than the previous one, in terms of the number of responses collected. This is because this survey is shorter and technically easiest than the other one; in the previous many people skip the survey when half was completed because of this problems and in this one, the problem has not occurred.

Thirty-two (32) respondents returned complete questionnaires. Most of the respondents are from organizations with rich experience and from many departments of construction engineering and management. Based on our site web page, 36 questionnaires were started, but after the analysis for see the validity of the answers and respondents, just 27 of them were valid. In totally, 5 questionnairess were returned after completion the hard copy word version, and the other 27 through the survey web.

The results collected correspond to many European countries, being the most participative Spain, Switzerland, England and Austria.

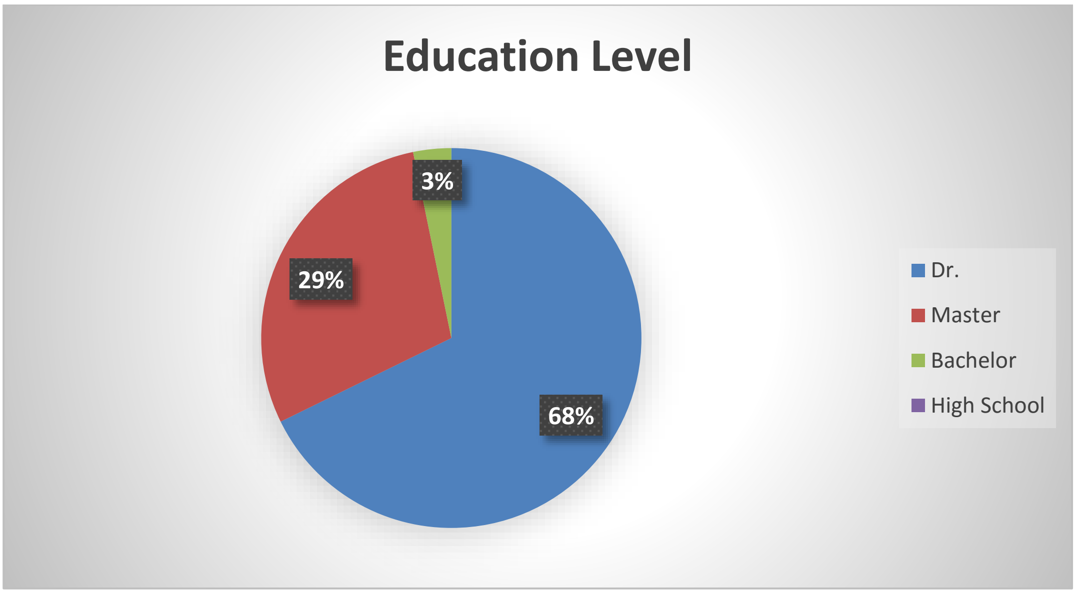
Figure 8. Background responses – European Countries



Analyzing the history of the responses obtained through benchmarking; we highlight the following:

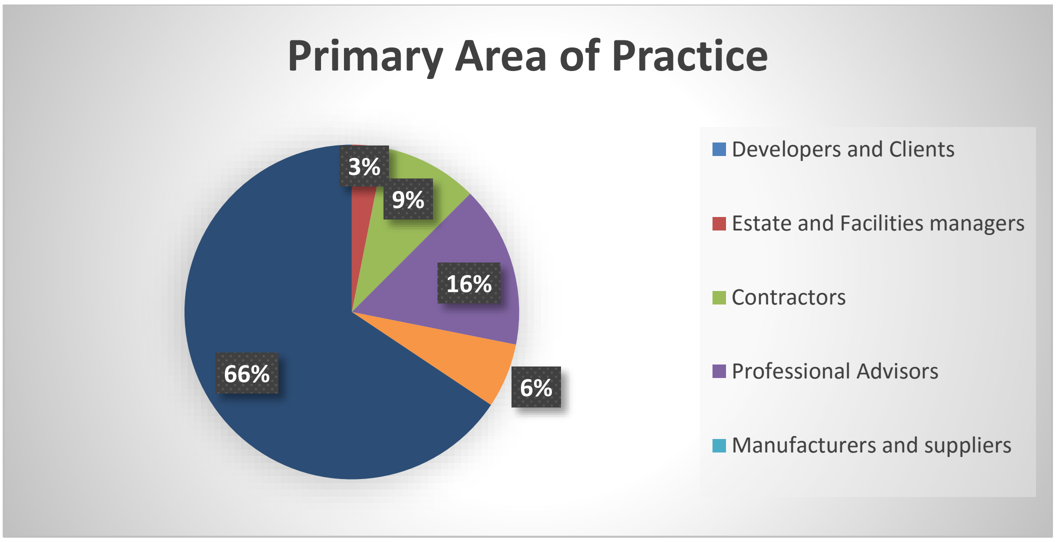
i. More than half of respondents (68%) have a corresponding doctor education level and 29% have a master. Only 3% of the respondents have just a bachelor education level and any of them have a high school education.

Figure 9. Background responses – Education Level



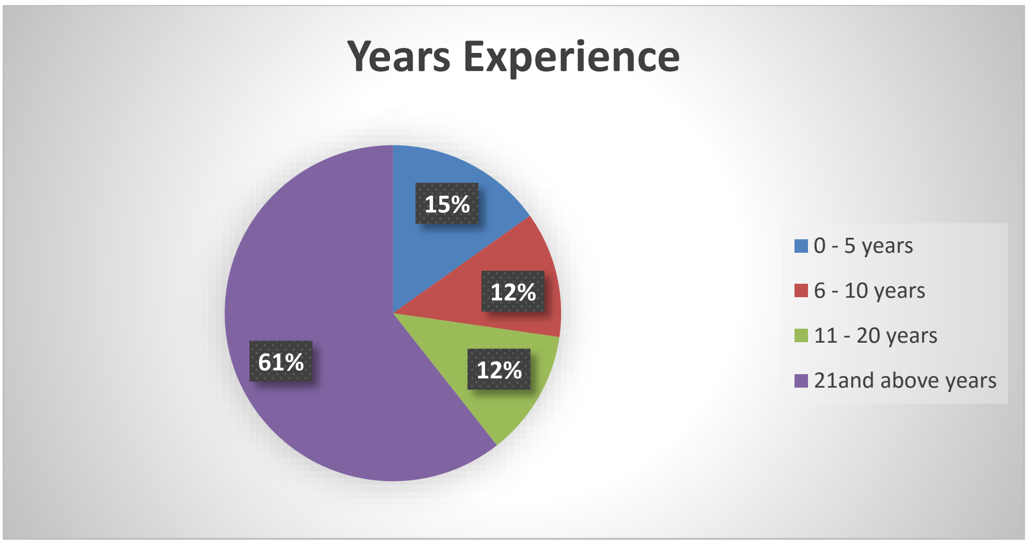
ii. The two major primary area of practice of respondents, have been professional advisors (16%) and universities and professional bodies (66%). The last one due the facility to contact them, because each university has clear directories of each department.

Figure 10. Background responses – Primary Area of Practrice



iii. 73% of the results obtained correspond to experienced people (61%, 21 years and above; 12% between 11 and 20 years) and 15% just to people with lack of experience in the construction industry.

Figure 11. Background responses – Years Experience



Based on the results corresponding to the previous background, we proceed to identify the most critical factors affecting the critical construction trades productivity.

4.5 IDENTIFYING THE CRITICAL FACTORS AFFECTING THE CONSTRUCTION TRADES

As previously explained, in this section an analyze has been carried out for seeing the criticality of the different factors affecting the labor productivity of the critical construction trades found previously for the Hong Kong case, by European people.

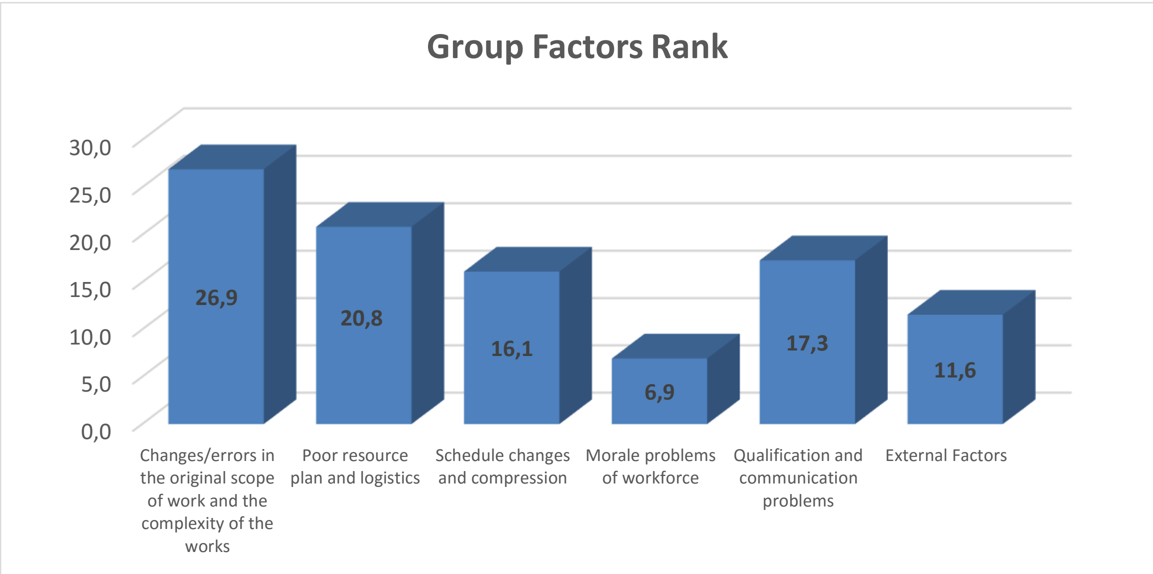
4.5.1 Group of factors affecting labor productivity

The group ranking according to the respective factors affecting labor productivity, as explained previously, is shown in the following table and figure. It was calculated by taking into consideration the average value of the respondent's answers.

Table 15. Group Factors Rank

Factors	Average Value (%)	Rank
Changes/erros in the original scope of work and the complexity of the works	26.9	1
Poor resource plan and logistics	20.8	2
Qualification and communication problems	17.3	3
Schedule changes and compression	16.1	4
External factors	11.6	5
Morale problems of workforce.	6.9	6

Figure 12. Group Factors Rank



Changes/errors in the original scope of work and the complexity of the works group were the top group with an average of 26.9% and morale problems of workforce group at the bottom rank with an average of 6.9%.

4.5.2 Changes/errors in the original scope of work and complexity of the work

Table 16 and figure 12 shows the ranking of the various factors of changes/errors in the original scope of work and complexity of work group. Design changes, errors and omissions were ranked first in the group rank and also in the overall rank with an RII value of 0.8 under a total of 1.0 (average of 4.0).

The complexity of construction method was ranked as the last one of the group and 18th in the overall factors rank, with an RII value of 0.631, corresponding to an average of 3.16 under 5 in the scale used for our respondents.

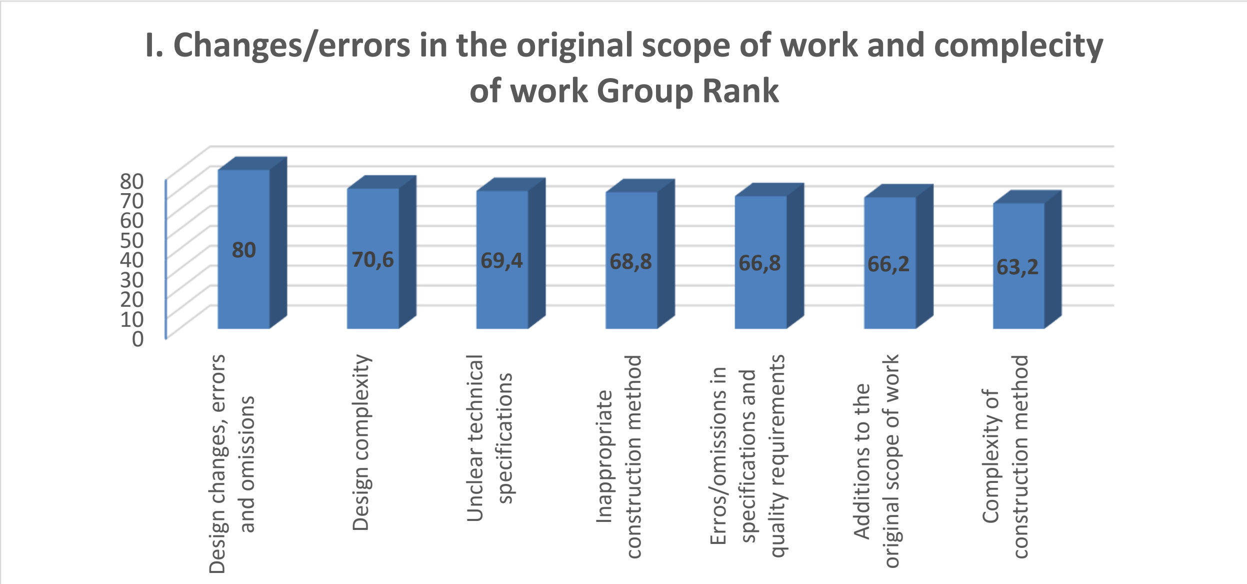
Table 16. Changes/errors in the original scope of work and complexity of work group rank

Factors	RII	Average	Group Rank	Overall Rank
Design changes, errors and omissions	0.800	4.00	1	1
Design complexity	0.706	3.53	2	6
Unclear technical specifications	0.694	3.47	3	7
Inappropriate construction method	0.688	3.44	4	9
Erros/omissions in specifications and quality requirements	0.669	3.34	5	12
Additions to the original scope of work	0.663	3.31	6	15
Complexity of construction method	0.631	3.16	7	18

The global average of this group is 3.46 (RII value, 0.692) and the range between the most critical factor and the less one is just 0.84 (RII value, 0.169). Both values illustrate the importance of the group, because of the high average, a value near the highest rank factor and the low dispersion of the factors among them. In addition, all factors being in this group are among the first 50% of the overall factors rank.

Finally, this group has four of the ten most critical factors of all the factors analyzed, being these: design changes, errors and omissions (1st, RII value of 0.8); design complexity (6th, RII value of 0.706); unclear technical specifications (7th, RII value of 0.694); and, inappropriate construction method (9th, RII value of 0.688).

Figure 13. Changes/errors in the original scope of work and complexity of work group rank



4.5.3 Poor resource plan and logistics

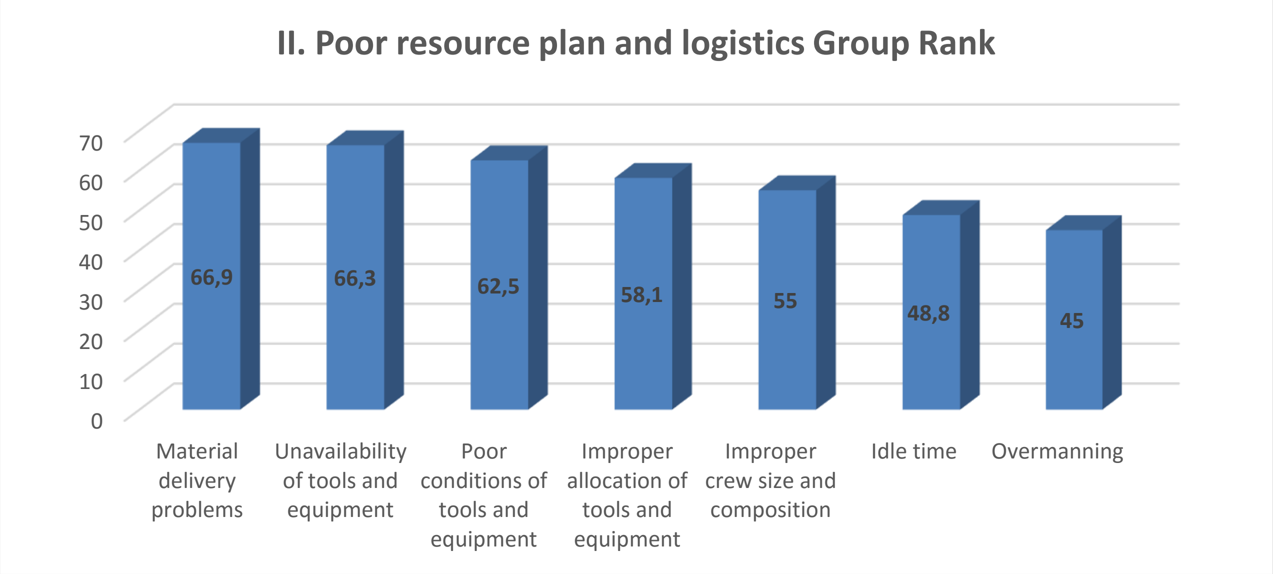
Table 17 and figure 13 illustrate the ranking of poor resource plan and logistics group factors rank. Material delivery problems were ranked first in the group rank and 13th among all 40 factors that negatively affect labor productivity of the critical construction trades, with an RII value of 0.669 under a total of 1.0 (average 3.34).

Overmanning was ranked as the last one of the group and 39th in the overall factors rank, with an RII value of 0.45, corresponding to an average of 2.25 under 5 in the scale used for our respondents.

Table 17. Poor resource plan and logistics group rank

Factors	RII	Average	Group Rank	Overall Rank
Material delivery problems	0.669	3.34	1	13
Unavailability of tools and equipment	0.663	3.31	2	16
Poor conditions of tools and equipment	0.625	3.13	3	19
Improper allocation of tools and equipment	0.581	2.91	4	26
Improper crew size and composition	0.550	2.75	5	29
Idle time	0.488	2.44	6	37
Overmanning	0.450	2.25	7	39

Figure 14. Poor resource plan and logistics group rank



The global average of this group is 2.87 (RII value, 0.575) and the range between the most critical factor and the less one is 1.09 (RII value, 0.219). The dispersion of values shown in this group can be translated as a group that has both important factors and the opposite. 2 factors of this group are in the ten less critical within the overall factors rank, being these: idle time (37th, RII value of 0.488) and overmanning (39th, RII value of 0.450).

4.5.4 Schedule changes and compression

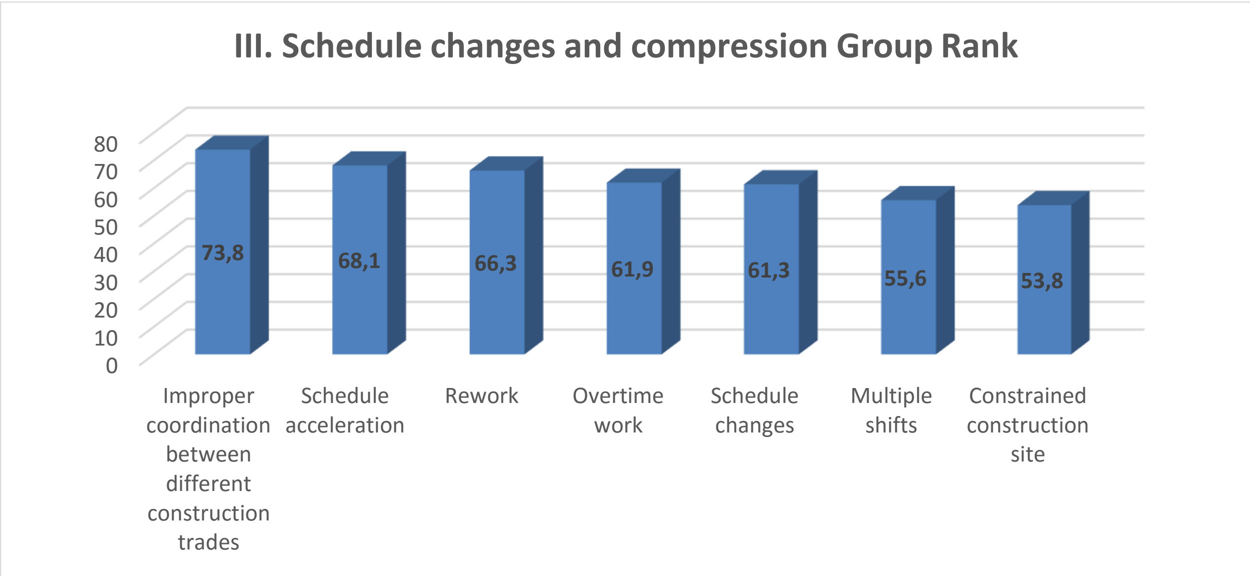
Table 18 and figure 14 shows the ranking of schedule changes and compression group factors rank. Improper coordination between different construction trades was ranked first in the group rank and 5th among all 40 factors that negatively affect labor productivity of the critical construction trades, with an RII value of 0.738 under a total of 1.0 (average 3.69). This factor is one of the ten most critical factors within the overall factors rank.

Constrained construction site was ranked as the last one of the group and 32nd in the overall factors rank, with an RII value of 0.538, corresponding to an average of 2.69 under 5 in the scale used for our respondents. This factor is one of the ten less critical within the overall factors rank.

Table 18. Schedule changes and compression group rank

Factors	RII	Average	Group Rank	Overall Rank
Improper coordination between different construction trades	0.738	3.69	1	5
Schedule acceleration	0.681	3.41	2	11
Rework	0.663	3.31	3	17
Overtime work	0.619	3.09	4	21
Schedule changes	0.613	3.06	5	23
Multiple shifts	0.556	2.78	6	28
Constrained construction site	0.538	2.69	7	32

Figure 15. Schedule changes and compression group rank



The global average of this group is 3.14 (RII value, 0.629) and the range between the most critical factor and the less one is 1.0 (RII value, 0.2). The dispersion of values shown in this group can be translate as a group that has both important factors and the opposite.

4.5.5 Morale problems of workforce

Table 19 and figure 15 illustrate the ranking of schedule morale problems of workforce group factors rank. Inconsistent rules of different supervision/management people were ranked first in the group rank and 20th among all 40 factors that negatively affect labor productivity of the critical construction trades, with an RII value of 0.625 under a total of 1.0 (average 3.13).

Worker absenteeism was ranked as the last one of the group and 38th in the overall factors rank, with an RII value of 0.475, corresponding to an average of 2.38 under 5 in the scale used for our respondents.

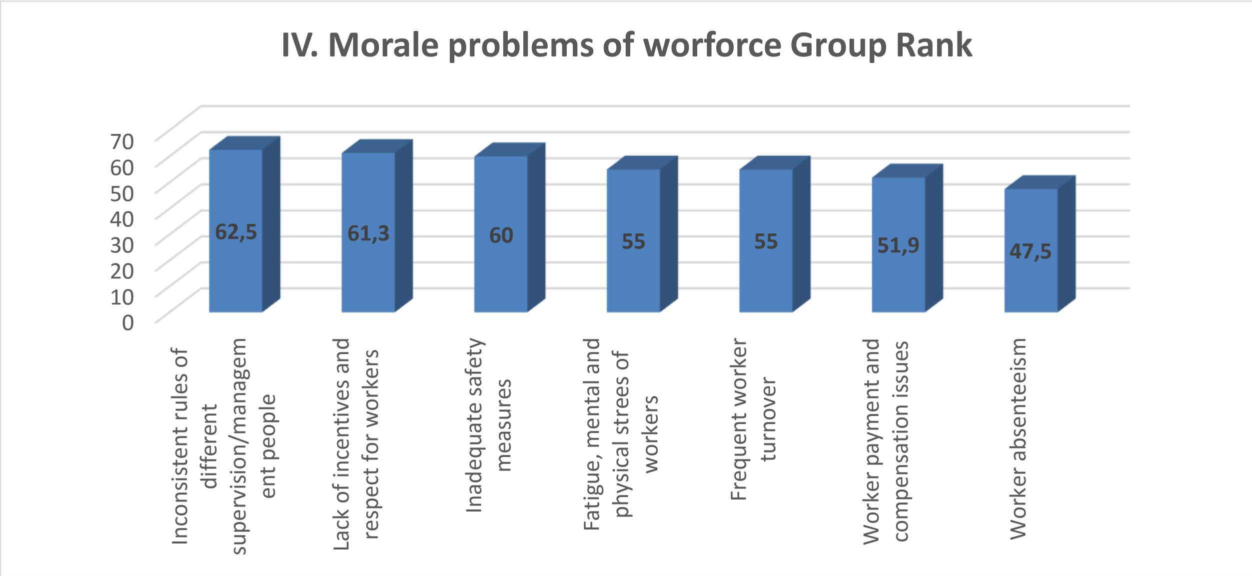
The global average of this group is 2.85 (RII value, 0.571) and the range between the most critical factor and the less one is just 0.75 (RII value, 0.150). Both values illustrate the low importance of the group, because of the low total average, a value near the highest rank factor and the low dispersion of the factors among them. In addition, all factors being in this group are among the last 50% of the overall factors rank.

Table 19. Morale problems of workforce group rank

Factors	RII	Average	Group Rank	Overall Rank
Inconsistent rules of different supervision/management people	0.625	3.13	1	20
Lack of incentives and respect for workers	0.613	3.06	2	24
Inadequate safety measures	0.600	3.00	3	25
Fatigue, mental and physical strees of workers	0.550	2.75	4	30
Frequent worker turnover	0.550	2.75	5	31
Worker payment and compensation issues	0.519	2.59	6	34
Worker absenteeism	0.475	2.38	7	38

Finally, this group has four of the ten less critical factors of all the factors analyzed, being these: fatigue, mental and physical stress of workers (30th, RII value of 0.55); frequent worker turnover (31th, RII value of 0.55); worker payment and compensation issues (34th, RII value of 0.519); and, worker absenteeism (38th, RII value of 0.475).

Figure 16. Morale problems of workforce group rank



4.5.6 Qualification and communication problems

Table 20 and figure 16 shows the ranking of qualification and communication problems group factors rank. Communication problems between management and workers were ranked first in the group rank and 2nd among all 40 factors that negatively affect labor productivity of the critical construction trades, with an RII value of 0.763 under a total of 1.0 (average 3.81).

Language barriers were ranked as the last one of the group and 36th in the overall factors rank, with an RII value of 0.494, corresponding to an average of 2.47 under 5 in the scale used for our respondents. This factor is one of the ten less critical within the overall factors rank.

The global average of this group is 3.41 (RII value, 0.682) and the range between the most critical factor and the less one is 1.34 (RII value, 0.269). The dispersion of values shown in this group can be translated as a group that has both important factors and the opposite. But the high total average found, illustrate the overall importance of this group within the forty total factors analyzed.

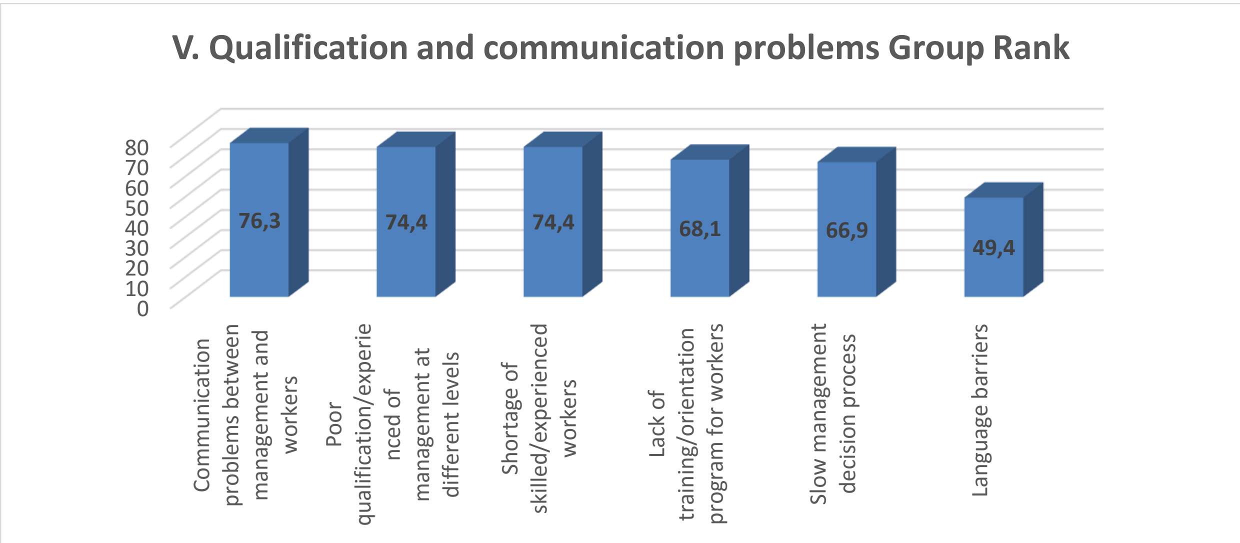
Four factors of this group are in the ten most critical within the overall factors rank, being these: communication problems between management and workers (2nd, RII value of 0.763); poor qualification/experienced of management at different levels (3rd, RII value of

0.744); shortage of skilled/experienced workers (4th, RII value of 0.744); and, lack of training/orientation program for workers (10th, RII value of 0.681).

Table 20. Qualification and communication problems group rank

Factors	RII	Average	Group Rank	Overall Rank
Communication problems between management and workers	0.763	3.81	1	2
Poor qualification/experienced of management at different levels	0.744	3.72	2	3
Shortage of skilled/experienced workers	0.744	3.72	3	4
Lack of training/orientation program for workers	0.681	3.41	4	10
Slow management decision process	0.669	3.34	5	14
Language barriers	0.494	2.47	6	36

Figure 17. Qualification and communication problems group rank



4.5.7 External factors

Table 21 and figure 17 shows the ranking of the external factors group rank. Unfavorable economic and financial conditions were ranked first in the group rank and 8th among all 40 factors that negatively affect labor productivity of the critical construction trades, with an RII value of 0.688 under a total of 1.0 (average 3.44), being one of the ten most critical factors within the overall factors.

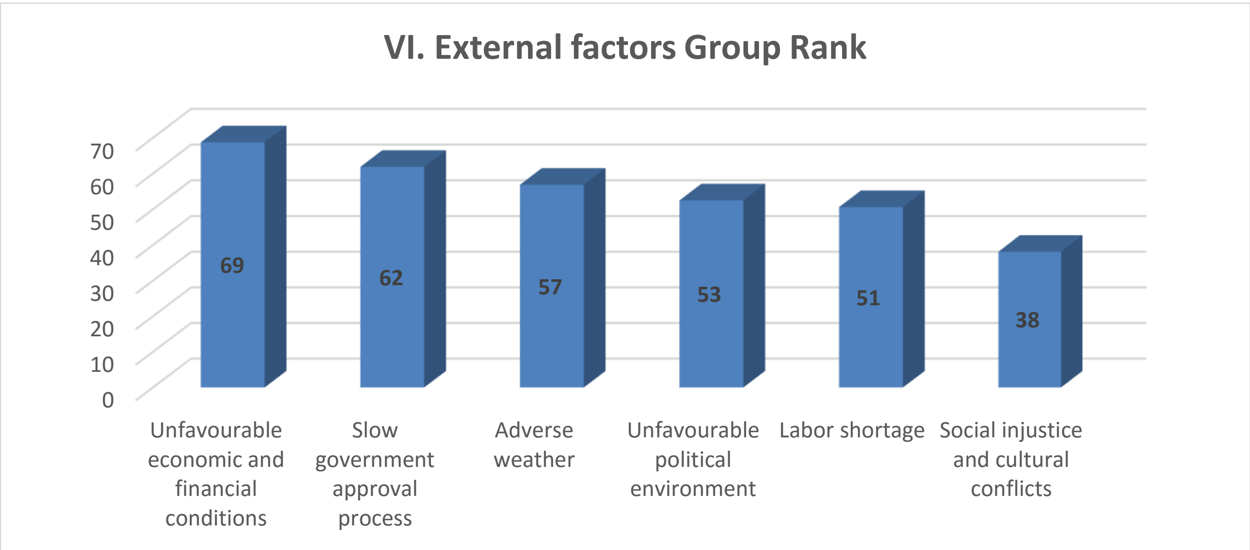
Social injustice and cultural conflicts were ranked as the last one of the group and also the last one, 40th, in the overall factors rank, with an RII value of 0.381, corresponding to an average of 1.91 under 5 in the scale used for our respondents. Is the only factor rated with less than an average of 2 by our respondents.

Table 21. External factors group rank

Factors	RII	Average	Group Rank	Overall Rank
Unfavourable economic and financial conditions	0.688	3.44	1	8
Slow government approval process	0.619	3.09	2	22
Adverse weather	0.569	2.84	3	27
Unfavourable political environment	0.525	2.63	4	33
Labor shortage	0.506	2.53	5	35
Social injustice and cultural conflicts	0.381	1.91	6	40

The global average of this group is 2.75 (RII value, 0.55) and the range between the most critical factor and the less one is 1.53 (RII value, 0.306), being the highest range within all the group factors. The dispersion of values shown in this group can be translated as a group that has both important factors and the opposite. But the low total average found, illustrate the overall low importance of this group within the forty total factors analyzed.

Figure 18. External factors group rank



Three factors of this group are in the ten less critical within the overall factors rank, being these: unfavorable political environment (33th, RII value of 0.525); labor shortage (35th, RII value of 0.506); and, social injustice and cultural conflicts (40th, RII value of 0.381).

4.5.8 Overall factors affecting labor productivity

Throughout the analysis done of the overall factors within their different groups, we obtain the following classification, shown in table 22 and figure 18.

Table 22. Overall Factors Rank

Overall Rank	Factors	RII	Average	Group Factor
1	Design changes, errors and omissions	0.800	4.00	I
2	Communication problems between management and workers	0.763	3.81	V
3	Poor qualification/experienced of management at different levels	0.744	3.72	V
4	Shortage of skilled/experienced workers	0.744	3.72	V
5	Improper coordination between different construction trades	0.738	3.69	III
6	Design complexity	0.706	3.53	I
7	Unclear technical specifications	0.694	3.47	I
8	Unfavorable economic and financial conditions	0.688	3.44	VI
9	Inappropriate construction method	0.688	3.44	I
10	Lack of training/orientation program for workers	0.681	3.41	V
11	Schedule acceleration	0.681	3.41	III
12	Erros/omissions in specifications and quality requirements	0.669	3.34	I
13	Material delivery problems	0.669	3.34	II
14	Slow management decision process	0.669	3.34	V
15	Additions to the original scope of work	0.663	3.31	I
16	Unavailability of tools and equipment	0.663	3.31	II
17	Rework	0.663	3.31	III
18	Complexity of construction method	0.631	3.16	I
19	Poor conditions of tools and equipment	0.625	3.13	II
20	Inconsistent rules of different supervision/management people	0.625	3.13	IV
21	Overtime work	0.619	3.09	III

22	Slow government approval process	0.619	3.09	VI
23	Schedule changes	0.613	3.06	III
24	Lack of incentives and respect for workers	0.613	3.06	IV
25	Inadequate safety measures	0.600	3.00	IV
26	Improper allocation of tools and equipment	0.581	2.91	II
27	Adverse weather	0.569	2.84	VI
28	Multiple shifts	0.556	2.78	III
29	Improper crew size and composition	0.550	2.75	II
30	Fatigue, mental and physical strees of workers	0.550	2.75	IV
31	Frequent worker turnover	0.550	2.75	IV
32	Constrained construction site	0.538	2.69	III
33	Unfavourable political environment	0.525	2.63	VI
34	Worker payment and compensation issues	0.519	2.59	IV
35	Labor shortage	0.506	2.53	VI
36	Language barriers	0.494	2.47	VI
37	Idle time	0.488	2.44	II
38	Worker absenteeism	0.475	2.38	IV
39	Overmanning	0.450	2.25	II
40	Social injustice and cultural conflicts	0.381	1.91	VI

Through the previous rank, we observe the following:

i. The overall average of the total factors rank is 3.07 (RII value of 0.615) under a total of 5 being the highest factor design changes, errors and omissions with an average of 4.0 (RII value of 0.8) and the lowest factor social injustice and cultural conflicts with an average of 1.91 (RII value of 0.381).

ii. Just one factor has an average equal or higher than 4 (very significant to extremely significant). Twenty-three (23) factors have an average between 3 and 4 (significant to very significant). Fifteen (15) factors have an average between 2 and 3 (fairly significant to significant). Just one factor has an average between 1 and 2 (low significant to fairly significant).

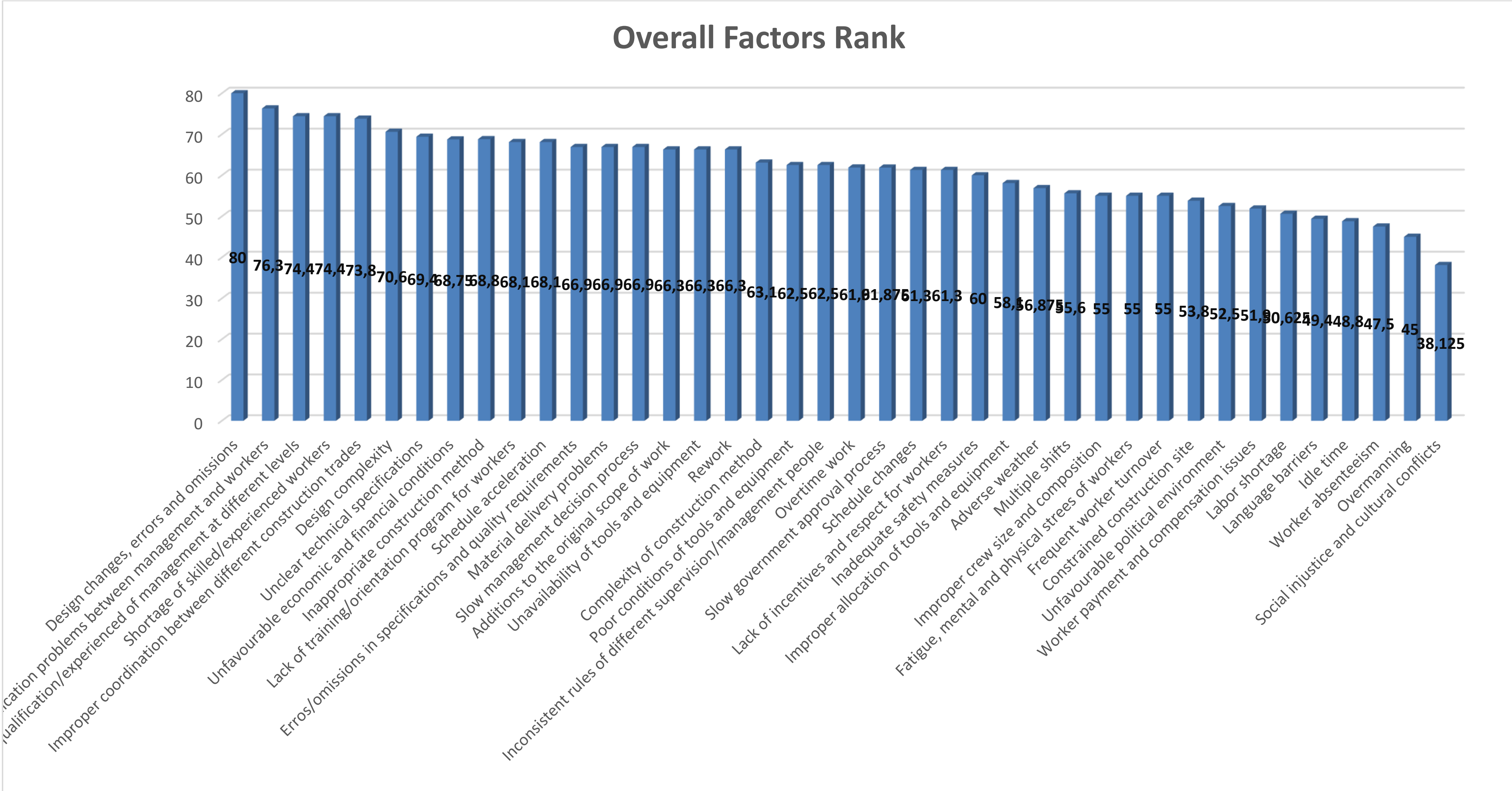
iii. Twenty-four (24) factors are between 3 and 5 (significant to extremely significant) and the global average is near 3 (significant); this translates into a relative importance of all the factors listed on our critical construction trades.

iv. Through the total relative importance index (RII) of the overall factors, we obtain the following classification. In this RII classification and the one our respondents rate by putting the weight, changes/errors in the original scope of work and complexity of works, and, qualification and communications problems have the same rank.

Table 23. RII Group Factors Rank

Group Factors	**RII**	**%**	**Rank**
I. Changes/errors in the original scope of work and complexity of works	4,851	19,7	1
II. Poor resource plan and logistics	4,026	16,4	4
III. Schedule changes and compression	4,408	17,9	2
IV. Morale problems of worforce	3,932	16,0	5
V. Qualification and communication problems	4,095	16,6	3
VI. External factors	3,288	13,4	6

Figure 19. Overall Factors Rank



4.5.9 Identifying the 10 most critical factors affecting labor productivity

The ten most critical factors affecting labor productivity for the critical construction trades previously analyzed are the ten with greater relative importance index (RII) among the forty (40) total analyzed. This rank is shown in the following table.

Table 24. 10 most critical factors affecting labor productivity

Overall Rank	Factors	RII	Average	Group Factor
1	Design changes, errors and omissions	0.800	4.00	I
2	Communication problems between management and workers	0.763	3.81	V
3	Poor qualification/experienced of management at different levels	0.744	3.72	V
4	Shortage of skilled/experienced workers	0.744	3.72	V
5	Improper coordination between different construction trades	0.738	3.69	III
6	Design complexity	0.706	3.53	I
7	Unclear technical specifications	0.694	3.47	I
8	Unfavourable economic and financial conditions	0.688	3.44	VI
9	Inappropriate construction method	0.688	3.44	I
10	Lack of training/orientation program for workers	0.681	3.41	V

The overall average of ten most critical factors affecting the critical construction trades is 3.62 (RII value of 0.725) under a total of five in the scale used by our respondents. The range of the rank is 0.59 (RII value of 0.119).

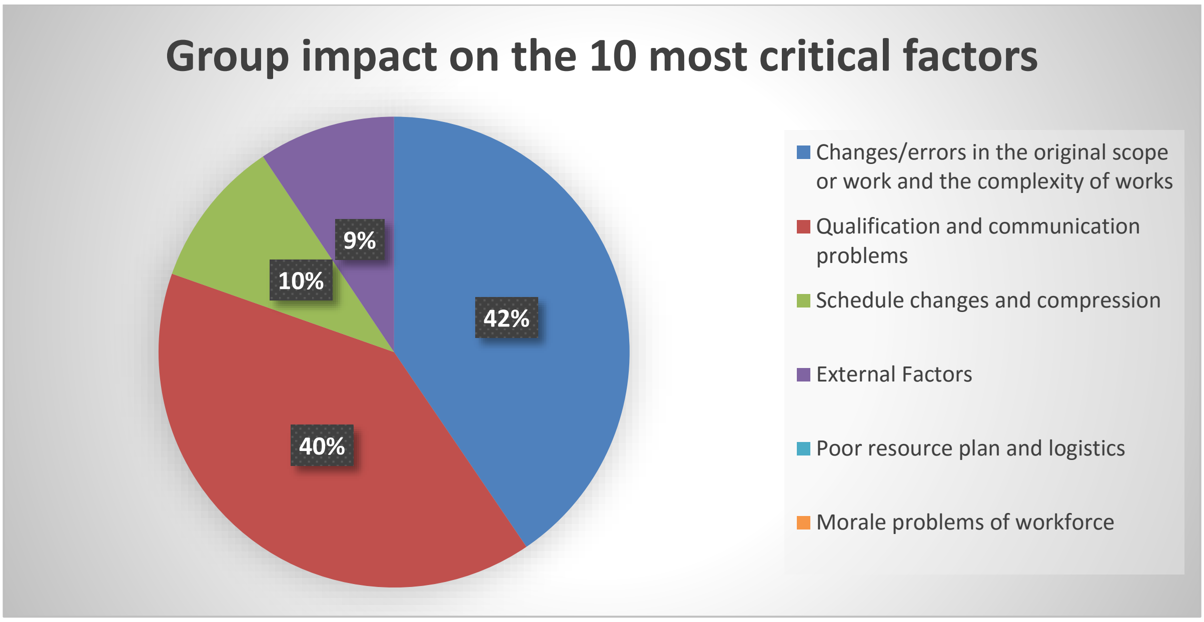
Qualification and communication problems group has the larger presence in this classification within a total of four factors with a total RII of 2.932 (40.5%). The present factors are the following: communication problems between management and workers; poor qualification/experienced of management at different levels; shortage of skilled/experienced workers; and, lack of training/orientation program for workers.

Changes/errors in the original scope of work and the complexity of works group have the second larger presence in this classification, within four factors of the group in the rank as well with a total RII of 2.888 (39.9%). The present factors in the rank are the following: design changes, errors and omissions; design complexity; unclear technical specifications; and, inappropriate construction method.

Schedule changes and compression group and external factors group have a low impact on the previous rank. Each group has only one factor on the rank being respectively, improper coordination between different construction trades with an RII value of 0.738 (10.2%) and unfavorable economic and financial conditions with an RII value of 0.688 (9.4%).

Both factors group, poor resource plan and logistics and morale problems of workforce don't appear in the rank and therefore have no impact on the 10 most critical construction trades affecting labor productivity.

Figure 20. Group impact on the 10 most critical factors



Design changes, errors and omissions were ranked 1st in the overall rank, with an RII of 0.8 and design complexity was ranked 6th, with an RII of 0.706. (Thomas et al. 1999) stated that "there is a 30% loss of efficiency when work changes are being performed". This result can be interpreted as changes to specifications and drawings that require additional time for adjustments of resources and manpower so that the change can be met. Also known as designer errors and omissions, these changes relate to plans that are incomplete or contain errors that are difficult to find until the construction contractor finds them well after the construction phase of the project has started. With most construction contracts, where the contractor bids on designs that are completed prior to contract award, the owner is liable for the designer's errors and omissions.

Communication problems between management and workers were ranked 2nd in the most critical factors rank, with an RII of 0.763 and unclear technical specifications were ranked 7th with an RII of 0.694. Problems related to work instructions among laborers can create disagreement among them and about the responsibilities for each laborer, which leads to a lot of mistakes in work and, consequently, affects labor productivity. Good communication is necessary to efficiently complete a project. Lack of sufficient communication can lead to the lack of worker motivation.

Poor qualification/experienced of management at different levels was ranked the 3rd with an RII of 0.744. Management at different levels concerns schedule and plan work and materials to make certain that no one is waiting for materials, labor, or the completion of another task. Poor management was responsible for a lot of time wasted on a jobsite. Proper management of construction projects requires knowledge of modern management techniques. A familiarity with general management knowledge and special knowledge domains are indispensable, while supporting disciplines such as computer based information systems is a plus. Good management skills include adopting a performance based management viewpoint. This involves setting priorities for improvements, provide cost efficient and easy to use methods, promote a supportive labor-management relationship, and cut costs while increasing profits.

Shortage of skilled/experienced workers has a great influence on productivity and was ranked 4th on the overall rank with an RII of 0.744. The craftsmen's experience affects labor productivity and the knowledge of the craftsman affects job-site productivity. Experience improves both the intellectual and physical abilities of laborers which, consequently, increases labor productivity.

Improper coordination between different construction trades was ranked 5th on the overall rank with an RII of 0.738. This factor may be one cause of construction delays, which incurs additional costs to the project. If the process is not adequate, some construction trades may need others, which if they are not available, reduces the productivity of workers who use them, and thus overall trades. Similar effects will happen if workers use the inappropriate construction method, factor ranked as 9th on the overall rank with an RII of 0.688.

Unfavorable economic and financial conditions were ranked 8th in the rank of the 10 most critical factors affecting labor productivity with an RII of 0.688. This external factor has a relative importance due the machinery that can be purchased for the project. Lack of proper materials and equipment is one cause of construction delays. Purchasing the proper equipment that matches the need of the job, is necessary in order to achieve the highest possible productivity. This factor has an impact too in other factors, as access issues, safety issues, skilled laborers and others.

Lack of training/orientation program for workers was ranked 10th in the overall group, with an RII of 0.681. Past studies from (Samson and Lema, 2002), (Cheung et al. 2004), and (Jha and Lyer, 2005) stated that persons entering the construction industry directly from high school usually start as inexperienced in the construction industry or as laborers. They can learn from their job quickly by working closely with experienced people. Whereas, skilled laborers, such as carpenters, bricklayers, plumbers, and other construction trade specialists, most often get their formal instruction by attending a local technical school or through an employer-provided training program.

CHAPTER 5. PRODUCTIVITY RATE OF CRITICAL TRADES

5.1 CASE STUDY

This chapter aims to improve the construction productivity in Europe by establishing a productivity questionnaire for the measurement of the critical construction trades through the continent.

The measurement of trade productivity is normally saved by contractors into a platform to carry out an in-depth analysis of their productivity performance. At the trade level, the amount of physical output per manhour is measured. A worker is deemed to be more productive if he produces more output within an hour. The indicator is calculated as follows:

$$Trade\ Productivity = \frac{Total\ units\ of\ output}{Total\ manhours}$$

The unit of measurement for trade productivity varies for different trades. For example, the unit of measurement for formwork installation is the area of formwork installed (m^2) per manhour while the unit of measurement for electrical conduit installation is the length of conduit installed (m) per manhour.

Through the questionnaires, we aim to achieve the following objectives:

i. To determine the productivity rate of each critical construction trade found previously for both infrastructure and building projects;

ii. To make comparisons with the Hong Kong results for the same trades, in order to see which trades are more productive in each region; and,

iiii. To determine the importance of questionnaires for data collection.

For this chapter, it is important to note that critical trades used for the productivity rate research are those found by my Hong Kong colleagues for the same reasons explained before (4.1).

5.2 ORGANIZATION OF THE QUESTIONNAIRE

The research was conducted by a structured questionnaire that was sent to different companies, and organizations through Europe, related to the construction. Some of them the same surveyed (not the one related to academic jobs) on the previously benchmarks.

For this part of the research, we just create a hard copy questionnaire survey in word format in order to give a more confidential aspect, because of the data we are asking for and dropped the online format.

This is the most complex part of the research, because of the confidentiality of the data sought and the difficulty of finding the right person who possesses them. During projects, normally there is just one expert who only works on that. Construction productivity data is part of the know-how of a company in making economic proposals and is relies heavely on each case. So, even when the person is found, he does not want to share this data with external company people.

At the beginning of the questionnaire, the background of this survey was explained, the aim of the survey, and warm them of the confidentiality of their responses. All of this in the first section called “Introduction to the Questionnaire Survey”. After this, we asked the respondents to complete different sections:

i. Section B “Background of Respondents”. In this part, they must complete different aspects related to their profile, some of which are optional. The different aspects are: name; organization; email address; job/position; primary area of practice; years of experience and education level.

iii. Section C “Productivity Rate of the Critical Construction trades”. They have to assign a productivity range and a productivity average to each of the critical construction trades, in the productivity units shown.

Table 25. Productivty data questionnaire format

Trade	Measurement Unit	**Productivity Range**		**Average**
		From	**To**	
x	output/manhour			

5.3 PRODUCTIVITY RATE OF CRITICAL CONSTRUCTION TRADES

Twenty (20) critical trades have been studied in this chapter for both infrastructure and building projects. Among them, five are common to both projects, being these: bar bender and fixer, woodworker, plant and equipment operator, welder, and, metal-steel worker. There is another common, concrete and grouting worker, but because of the different nature according to the project, different measurement units have been put it. All of these illustrated on the following table.

Table 26. Construction trades productivity measurement

Construction Trade		Measurement Unit
Bar Bender and Fixer	Bar bender	kg/manhour
	Steel fixer	kg/manhour
Concrete and Grouting Worker (building projects)	To grout the floor	m^3/manhour
	To grout the beam	m^3/manhour
	To grout the column	m^3/manhour
Rigger/Metal Formwork Erector		kg/manhour
Woodworker		m^2/manhour
Welder		m/manhour
Metal-steel Worker		kg/manhour
Scaffolder		m^2/manhour
Piling Operative		m/manhour
Plant and Equipment Operator	Piling (master)	m/manhour
	Excavator	m^3/manhour
	Tower crane	m^2/manhour
Curtain Wall and Glass Panes Installer	Curtain wall installer	m^2/manhour
	Glazier	m^2/manhour
Piling Operative		m/manhour
Tunnel Worker		m/manhour
Concrete and Grouting Worker (infrastructure projects)		m^3/manhour
Electrician		m/manhour
Prestressing Operative		kg/manhour

Note: The trades in bold are the same critical trades both in Building Project and Infrastructure Project

Because of the difficulty in obtaining the data required as explained before, just one questionnaire was completed (not every trade) and returned with the following results:

Table 27. Productivity data for building construction trades

Construction Trade		Measurement Unit	Productivity Range		Average
			From	**To**	
Bar Bender and Fixer	Bar bender	kg/manhour			
	Steel fixer	kg/manhour	80	140	112
Concrete and Grouting Worker	To grout the floor	m^3/manhour	0.7	0.9	0.8
	To grout the beam	m^3/manhour	0.2	0.3	0.25
	To grout the column	m^3/manhour	0.4	0.6	0.5
Rigger/Metal Formwork Erector		kg/manhour	0.02	0.03	0.025
Woodworker		m^2/manhour	1.7	0.3	2
Welder		m/manhour	1.5	2.7	2.1
Metal-steel Worker		kg/manhour	70	100	85
Scaffolder		m^2/manhour	2.7	4.2	3.45
Piling Operative		m/manhour			
Plant and Equipment Operator	Piling (master)	m/manhour			
	Excavator	m^3/manhour	2	4	3
	Tower crane	m^2/manhour			
Curtain Wall and Glass Panes Installer	Curtain wall installer	m^2/manhour	6.7	9.2	7.95
	Glazier	m^2/manhour	2	4	3

Table 28. Productivity data for infrastructure construction trades

Construction Trade		Measurement Unit	Productivity Range		Average
			From	**To**	
Bar Bender and Fixer	Bar bender	kg/manhour	35	45	40
	Steel fixer	kg/manhour			
Piling Operative		m/manhour	10	16	13
Tunnel Worker		m/manhour			
Concrete and Grouting Worker		m^3/manhour	2.3	3.2	2.75
Metal-steel Worker		kg/manhour			
Electrician		m/manhour	3	4	3.5
Welder		m/manhour			
Prestressing Operative		kg/manhour			
Woodworker		m^2/manhour	2	2.66	2.33
Plant and Equipment Operator	Piling (master)	m/manhour			
	Excavator	m^3/manhour	5	7	6
	Tower crane	m^2/manhour	2	6	4

CHAPTER 6. STUDY COMPARISON BETWEEN HONG KONG AND EUROPE

6.1 CASE STUDY

This chapter aims to improve the construction productivity in the construction industry by comparison of two studies with the same objectives but in different regions; Europe and Hong Kong.

The mixture of both projects may indicate which aspects need to be improved in each region, depending on the other. In order to see this, we decided to make the following comparisons:

i. Comparison between the ten most critical construction trades in each region for both infrastructure and building projects;

ii. Comparison between the most critical factors affecting the critical construction trades labor productivity in both regions and the importance of the different group factors;

iii. Comparison between the productivity rate obtained for both infrastructure and building projects of the critical construction trades in both regions; and,

iv. To make conclusions by the mixture of both studies in order to improve the labor productivity in the construction industry.

6.2 CRITICAL CONSTRUCTION TRADES COMPARISON

In the previous analysis did in the chapter 3 we obtained the ten most critical construction trades according to the European respondents related to the construction industry. Below we will analyze what impact such operations have in the Hong Kong case.

In order to make a comparison as accurate as possible, it is necessary to make it through two different parts, which are:

i. Comparison of the most critical construction trades, their automated level and their level of shortage for Europe to see their impact in the Hong Kong case for the building projects.

ii. The same as explained above (i.) but this time for infrastructure projects.

6.2.1 – Building Projects Comparison

A. Europe Critical construction trades comparison for building projects

The following table and figure illustrate the criticality rank of the construction trades for the Europe case for building projects and their relative position in the Hong Kong case.

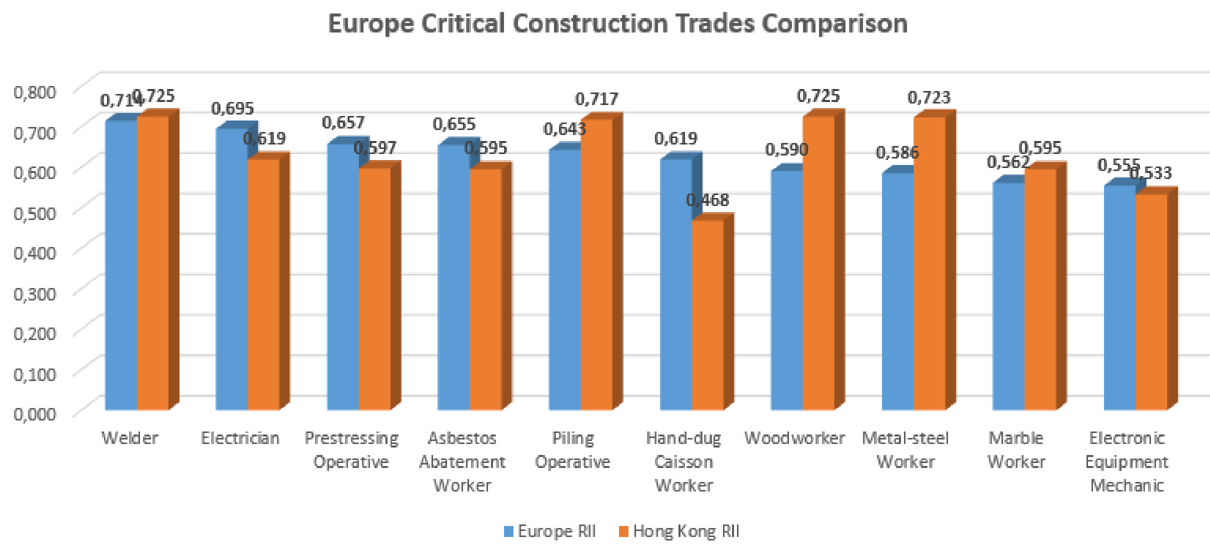
The critical construction trades takes a total RII average value of 0.628 for Europe and 0.629 for the Hong Kong case. These results shows the importance for this construction trades related to their producitivtiy in both regions, an importance that may be similar. Four of the Europe critical construction trades are the same for Hong Kong, being these: welder; piling operative; woodworker; and, metal-steel worker.

Table 29. Europe Critical Construction Trades Comparison (building projects)

Europe Overall Rank	Europe Critical Construction Trades	Europe RII	Hong Kong RII	Hong Kong Overall Rank
1	Welder	0,714	0,725	5
2	Electrician	0,695	0,619	13
3	Prestressing Operative	0,657	0,597	16
4	Asbestos Abatement Worker	0,655	0,595	18
5	Piling Operative	0,643	0,717	8
6	Hand-dug Caisson Worker	0,619	0,468	37
7	Woodworker	0,590	0,725	4
8	Metal-steel Worker	0,586	0,723	6
9	Marble Worker	0,562	0,595	17
10	Electronic Equipment Mechanic	0,555	0,533	29

In order to improve the productivity of the European critical construction trades, a mixture of both regions can be made. The following trades have a less importance in Hong Kong respective than Europe: electrician; prestressing operative; asbestos abatement worker; and, hand-dug caisson worker. This translates that in Hong Kong they are more productive in this trades, so a learning for them should be done.

Figure 21. Europe Critical Construction Trades Comparison (building projects)



B – Europe Labor shortage critical construction trades comparison for building projects

The following table and figure show the Europe critical construction trades and their related labor shortage criticality for both regions, Europe and Hong Kong, for building projects.

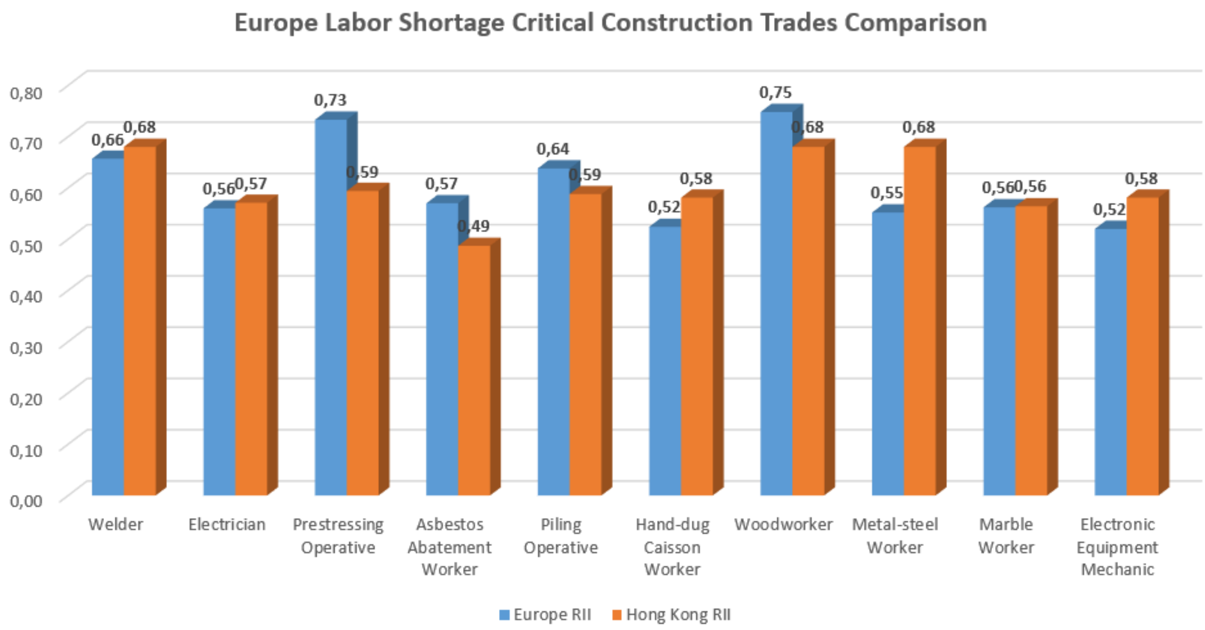
The labor shortage of the critical construction trades takes a total RII average value of 0.606 for Europe and 0.601 for the Hong Kong case. These results shows a similar labor shortage related to these operations in Europe than in Hong Kong. Just two of them are ranked in both regions into the ten most critical labor shortage trades, being these: welder and woodworker.

In order to improve the productivity of the European critical construction trades related to the labor shortage, a mixture of both regions can be made. The following trades have a significant highest labor shortage in Europe than in Hong Kong: prestressing operative; asbestos abatement worker; piling operative; and, woodworker. These construction trades can be improved looking into the Hong Kong building projects.

Table 30. Europe Labor Shortage Construction Trades Comparison (building projects)

Europe Overall Rank	Europe Critical Construction Trades	Europe RII	Hong Kong RII	Hong Kong Overall Rank
5	Welder	0,657	0,680	6
12	Electrician	0,560	0,571	20
1	Prestressing Operative	0,733	0,594	16
9	Asbestos Abatement Worker	0,570	0,487	36
6	Piling Operative	0,638	0,588	17
16	Hand-dug Caisson Worker	0,524	0,581	19
3	Woodworker	0,748	0,68	4
14	Metal-steel Worker	0,552	0,68	5
11	Marble Worker	0,562	0,564	21
19	Electronic Equipment Mechanic	0,520	0,581	18

Figure 22. Europe labor shortage critical construction trades comparison (building projects)



C – Europe automation level construction trades comparison for building projects

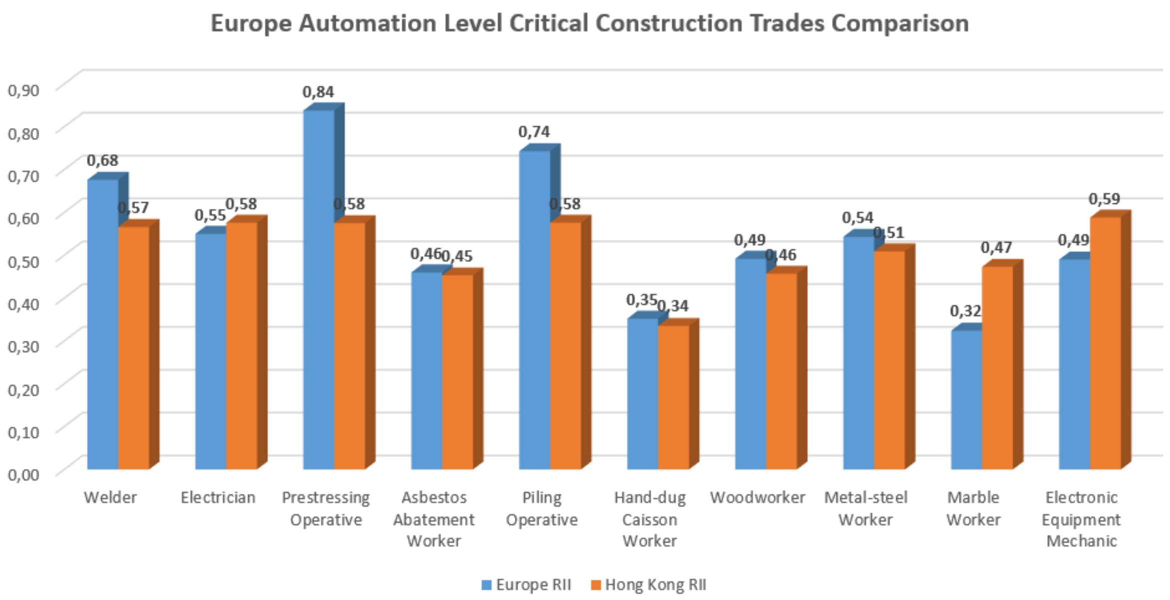
The following table and figure show the Europe critical construction trades and their related automation level for both regions, Europe and Hong Kong, for building projects.

The automation level of the critical construction trades takes a total RII average value of 0.547 for Europe and 0.511 for the Hong Kong case. These results shows a similar automated level related to these operations in Europe than in Hong Kong, but both of them really low related to the maximum possible, 1.0. Just two of them are ranked in both regions into the ten most automated trades, being these: prestressing operative and piling operative.

Table 31. Europe automation level critical construction trades comparison (building projects)

Europe Overall Rank	Europe Critical Construction Trades	Europe RII	Hong Kong RII	Hong Kong Overall Rank
6	Welder	0,676	0,566	12
13	Electrician	0,550	0,576	7
1	Prestressing Operative	0,838	0,575	9
24	Asbestos Abatement Worker	0,460	0,453	28
3	Piling Operative	0,743	0,576	8
33	Hand-dug Caisson Worker	0,352	0,335	37
20	Woodworker	0,492	0,457	27
15	Metal-steel Worker	0,543	0,509	21
36	Marble Worker	0,324	0,473	24
22	Electronic Equipment Mechanic	0,490	0,588	4

Figure 23. Europe automation level critical construction trades lomparison (building projects)



In order to improve the productivity of the European critical construction trades, a mixture of both regions can be made for improving their automation level. The following trades are significant more automated in Hong Kong than in Europe: marble worker and electronic equipment mechanic. These construction trades can be improved looking how they do this trades in Hong Kong during the building projects.

6.2.2 – Infrastructure Projects Comparison

A. Europe critical construction trades comparison for infrastructure projects

The following table and figure illustrate the criticality rank of the construction trades for the Europe case for infrastructure projects and their relative position in the Hong Kong case.

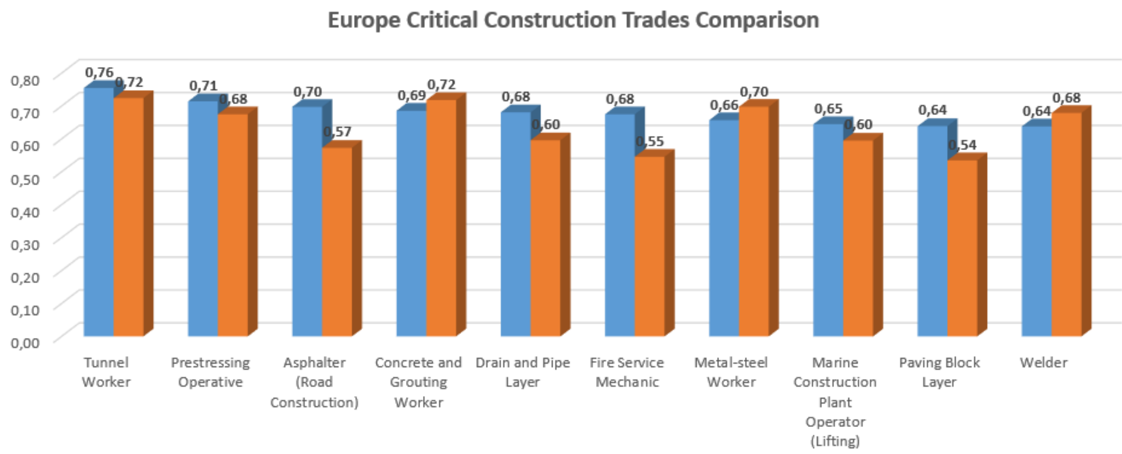
The critical construction trades takes a total RII average value of 0.679 for Europe and 0.634 for the Hong Kong case. These results shows the importance for this construction trades related to their producitivty in both regions, an importance that is a little bit higher in Europe (+0.045). Four of the europe critical construction trades are the same for Hong Kong, being these: tunnel worker; concrete and grouting worker; metal-steel worker; and, welder.

Table 32. Europe Critical Construction Trades Comparison (infrastructure projects)

Europe Overall Rank	Europe Critical Construction Trades	Europe RII	Hong Kong RII	Hong Kong Overall Rank
1	Tunnel Worker	0,755	0,724	3
2	Prestressing Operative	0,714	0,675	10
3	Asphalter (Road Construction)	0,698	0,573	30
4	Concrete and Grouting Worker	0,686	0,718	4
5	Drain and Pipe Layer	0,681	0,596	24
6	Fire Service Mechanic	0,675	0,546	33
7	Metal-steel Worker	0,657	0,698	6
8	Marine Construction Plant Operator (Lifting)	0,645	0,595	25
9	Paving Block Layer	0,639	0,535	35
10	Welder	0,638	0,679	8

In order to improve the productivity of the European critical construction trades, a mixture of both regions can be made. The following trades have a significant less importance in Hong Kong respective than Europe: asphalter (road construction); drain and pipe layer; fire service mechanic; and, paving block layer. This translates that in Hong Kong they are more productive in this trades, so a learning for them should be done.

Figure 24. Europe Critical Construction Trades Comparison (infrastructure projects)



B – Europe labor shortage construction trades comparison for infrastructure projects

The following table and figure show the Europe critical construction trades and their related labor shortage criticality for both regions, Europe and Hong Kong, for infrastructure projects.

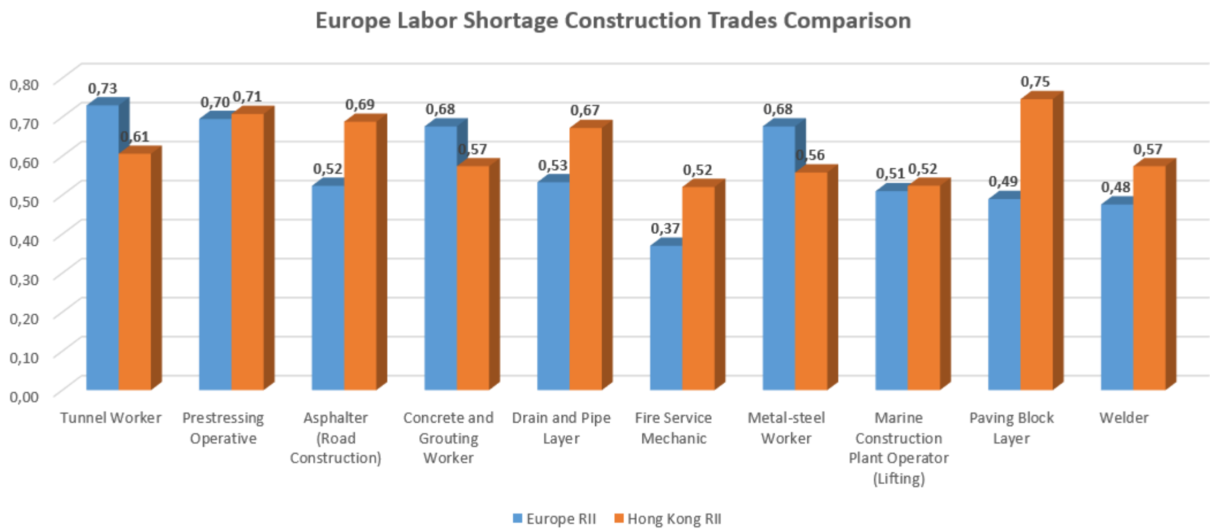
The labor shortage of the critical construction trades takes a total RII average value of 0.568 for Europe and 0.617 for the Hong Kong case. These results shows a highest labor shortage related to these operations in Hong Kong than in Europe. Just one of them is ranked in both regions into the ten most critical labor shortage trades, being prestressing operative.

Table 33. Europe Labor Shortage Construction Trades Comparison (infrastructure projects)

Europe Overall Rank	Europe Critical Construction Trades	Europe RII	Hong Kong RII	Hong Kong Overall Rank
1	Tunnel Worker	0,730	0,606	17
2	Prestressing Operative	0,695	0,708	5
14	Asphalter (Road Construction)	0,524	0,688	9
4	Concrete and Grouting Worker	0,676	0,574	22
11	Drain and Pipe Layer	0,533	0,672	13
34	Fire Service Mechanic	0,370	0,521	32
3	Metal-steel Worker	0,676	0,558	26
16	Marine Construction Plant Operator (Lifting)	0,510	0,524	31
21	Paving Block Layer	0,490	0,746	2
27	Welder	0,476	0,574	23

In order to improve the productivity of the European critical construction trades related to the labor shortage, a mixture of both regions can be made. The following trades have a significant highest labor shortage in Europe than in Hong Kong: tunnel worker; concrete and grouting worker; and, metal-stell worker. These construction trades can be improved looking into the Hong Kong infrastructure projects.

Figure 25. Europe Labor Shortage Construction Trades Comparison (infrastructure projects)



C – Europe automation level construction trades comparison for infrastructure projects

The following table and figure show the europe critical construction trades and their related automation level for both regions, Europe and Hong Kong, for infrastructure projects.

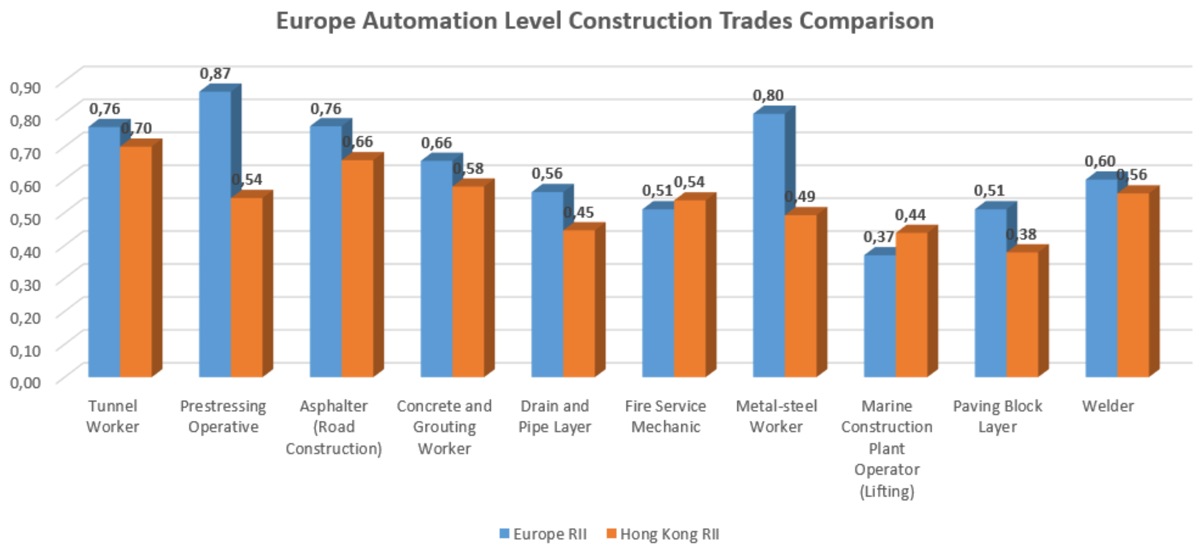
The automation level of the critical construction trades takes a total RII average value of 0.640 for Europe and 0.533 for the Hong Kong case. These results shows a highest automated level related to these operations in Europe than in Hong Kong. Just two of them are ranked in both regions into the ten most automated trades, being these: tunnel worker and asphalter (road construction).

In order to improve the productivity of the European critical construction trades, a mixture of both regions can be made for improving their automation level. The following trades are significant more automated in Hong Kong than in Europe: fire service mechanic and marine construction plant operator (lifting). These construction trades can be improved looking how they do this trades in Hong Kong during the different infrastructure projects.

Table 34. Europe Automation Level Construction Trades Comparison (infrastructure projects)

Europe Overall Rank	Europe Critical Construction Trades	Europe RII	Hong Kong RII	Hong Kong Overall Rank
4	Tunnel Worker	0,760	0,700	1
1	Prestressing Operative	0,867	0,544	14
3	Asphalter (Road Construction)	0,762	0,659	2
7	Concrete and Grouting Worker	0,657	0,579	10
12	Drain and Pipe Layer	0,562	0,446	30
17	Fire Service Mechanic	0,510	0,537	16
2	Metal-steel Worker	0,800	0,492	22
37	Marine Construction Plant Operator (Lifting)	0,370	0,438	31
16	Paving Block Layer	0,510	0,379	37
11	Welder	0,600	0,558	12

Figure 26. Europe Automation Level Construction Trades Comparison (infrastructure projects)



6.3 CRITICAL FACTORS AFFECTING THE CRITICAL TRADES COMPARISON

In order to make a comparison as accurate as possible, it is necessary to make it through three different parts, which are:

i. Comparison of the rated weights of the group factors for both regions.

ii. The impact of the ten Europe most critical factors in Hong Kong.

iii. The impact of the ten Hong Kong most critical factors in Europe.

6.3.1 – Group Factors Comparison

The following table and figure illustrate similar conclusions related to the most important group factors. Changes/errors in the original scope of work and the complexity of the works is the most critical group factors for both regions, with an average of 26.91% and 28.75% for Europe and Hong Kong respectively. Poor resource plan and logistics were rated as the second most critical in both cases with an average value of 20.84% for Europe and 21.50% for Hong Kong. We can observe that the range of the two most important groups is minimal, and little most critical for Hong Kong with +1.8% and +0.66% for the first and second group factors respectively.

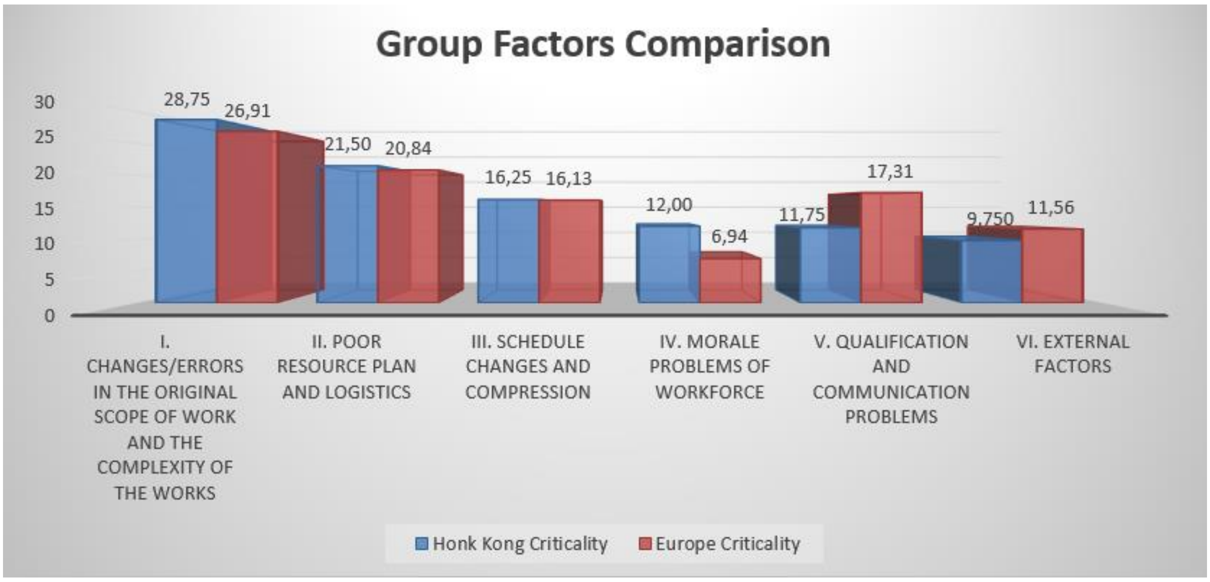
The third most critical group factor was qualification and communication problems for Europe with an average of 17.31% and schedule changes and compression for Hong Kong with an average of 16.25%. The third one for Hong Kong is rated as the fourth for Europe with an average of 16.13%, the range is minimum, +0.12% for Hong Kong, so we can say that the relative importance of both regions is the same. We cannot say the same for qualification and communication problems, rated as the fifth for Hong Kon, average 11.75%.

Table 35. Group factors comparison

Group Factors	Europe Average (%)	Europe Rank	Hong Kong Average (%)	Hong Kong Rank
I. Changes/erros in the original scope of work and the complexity of the works	26.91	1	28.75	1
II. Poor resource plan and logistics	20.84	2	21.50	2
III. Schedule changes and compression	16.13	4	16.25	3
IV. Morale problems of worforce	6.94	6	12.00	4
V. Qualification and communication problems	17.31	3	11.75	5
VI. External factors	11.56	5	9.75	6

Morale problems of workforce is rated as the last one for Europe with and average of 6.94% and fourth for Hong Kong with an average of 12%. There is a large average between both regions, +5.06% for Hong Kong. Finally, external factors is the lowest critical group factors for Hong Kong with an average of 9.75% and the fifth for Europe according to its average, 11.56%. The importance of this group is similar in both regions, with a range of +1.81% for Europe.

Figure 26. Group factors comparison



6.3.2 – Europe critical factors affecting the critical trades comparison

The following table and figure show the comparison of the Europe critical factors affecting the critical trades for the Hong Kong case. The RII average of the Europe critical factors is 0.725, and the same factors for Hong Kong, have an RII average of 0.84. This can be translated into an average of 3.63 and 4.2 respectively under 5 by the scale used by our respondents. We can observe the high average that this factors mean to Hong Kong, even if they are no their most critical. Note that the average of this factors for Hong Kong is even higher than the most critical factor for Europe, having an average of 4.0 under 5.

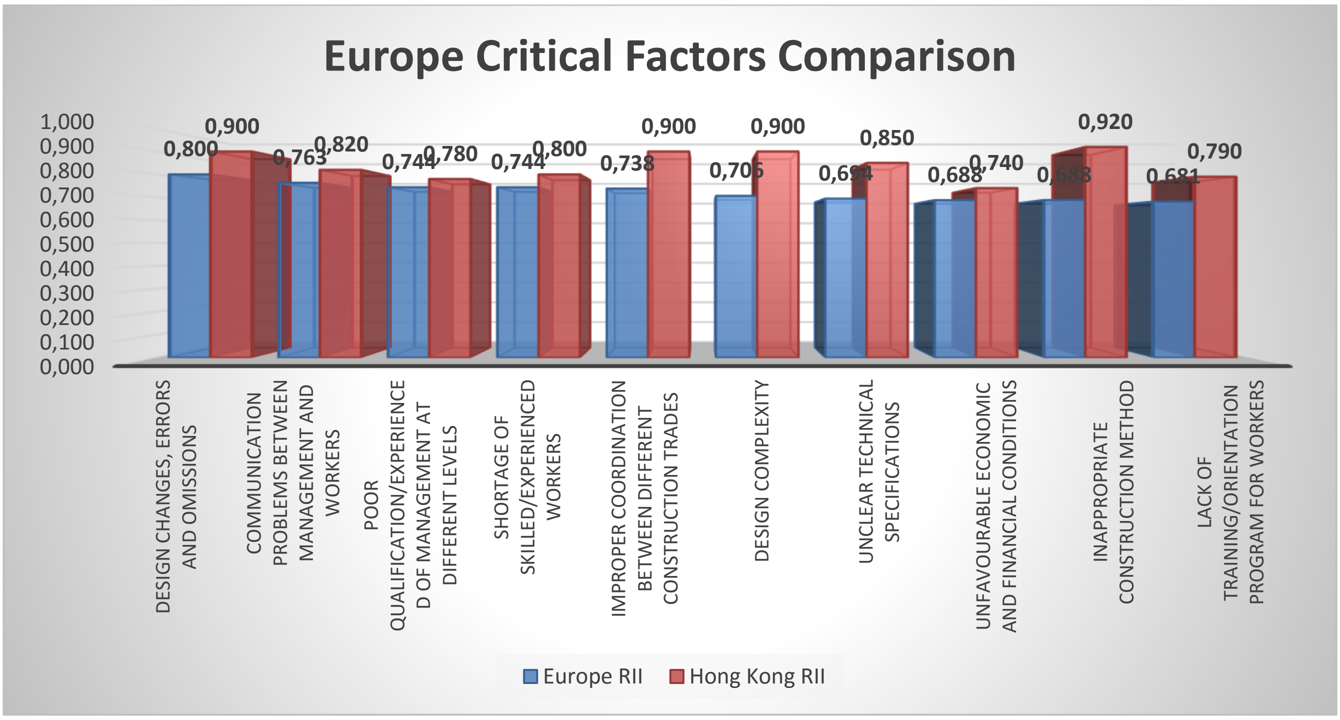
Four factors are both critical in Hong Kong and Europe, being these: design changes, errors and omissions; improper coordination between different construction trades; design complexity; and, inappropriate construction method. All these factors take the highest RII in the Hong Kong case.

Table 36. Europe critical factors comparison

Europe Overall Rank	Europe Critical Factors	Europe RII	Hong Kong RII	Hong Kong Overall Rank
1	**Design changes, errors and omissions**	0,800	0,900	4
2	Communication problems between management and workers	0,763	0,820	17
3	Poor qualification/experienced of management at different levels	0,744	0,780	22
4	Shortage of skilled/experienced workers	0,744	0,800	20
5	**Improper coordination between different construction trades**	0,738	0,900	7
6	**Design complexity**	0,706	0,900	5
7	Unclear technical specifications	0,694	0,850	13
8	Unfavourable economic and financial conditions	0,688	0,740	33
9	**Inappropriate construction method**	0,688	0,920	1
10	Lack of training/orientation program for workers	0,681	0,790	21

Note: The factors in bold are the same critical factors for both Europe and Hong Kong.

Figure 28. Europe critical factors comparison



6.3.3 – Hong Kong critical factors affecting the critical trades comparison

The following table and figure show the comparison of the Hong Kong critical factors affecting the critical trades for the Europe case. The RII average of the Hong Kong critical factors is 0.895, and the same factors for Europe, have an RII average of 0.670. This can be translated into an average of 4.48 and 3.35 respectively under 5 by the scale used by our respondents.

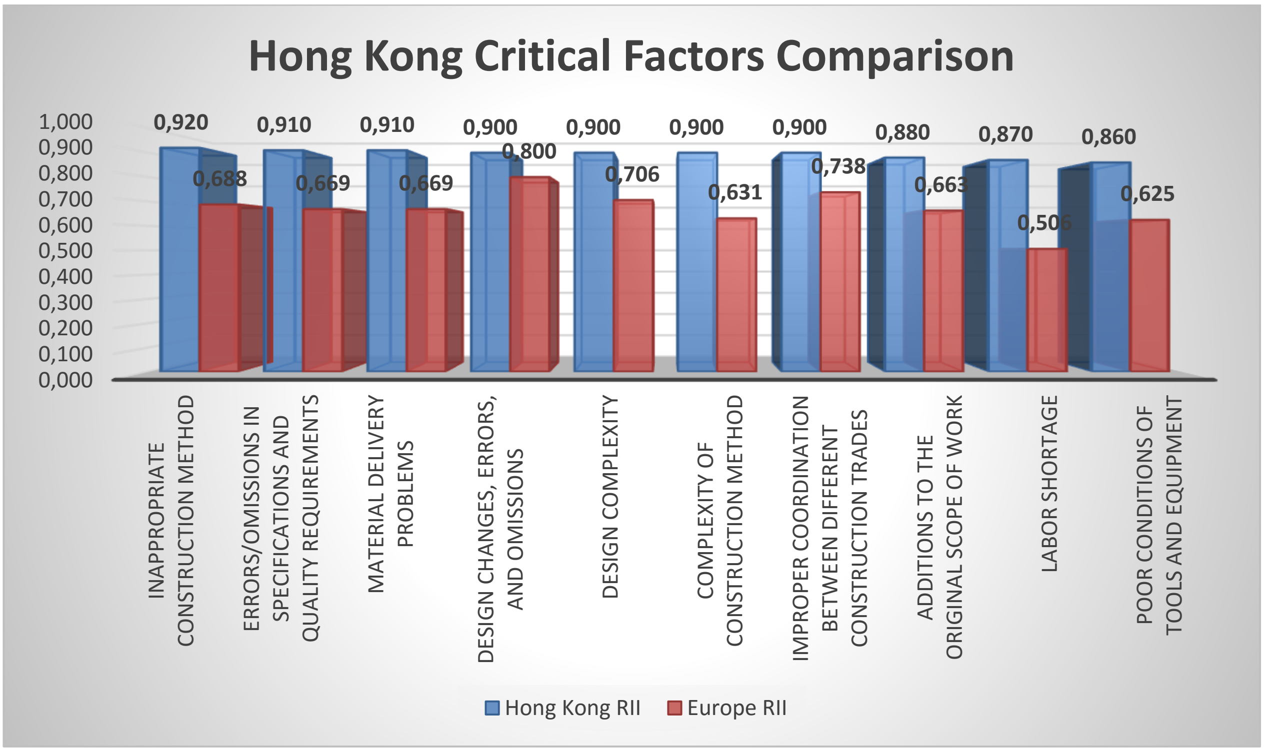
All these critical factors are rated as the most 50% critical factors in the overall Europe rank, except labor shortage which takes the 35th position. Even this, we can observe a high range average between both regions (RII value of 0.226). Note that the ten most critical factors have all of them a highest relative importance index (RII) than the most critical for Europe.

Table 37. Hong Kong critical factors comparison

Hong Kong Overall Rank	Factors	Hong Kong RII	Europe RII	Europe Overall Rank
1	**Inappropriate construction method**	0,920	0,688	9
2	Errors/omissions in specifications and quality requirements	0,910	0,669	12
3	Material delivery problems	0,910	0,669	13
4	**Design changes, errors, and omissions**	0,900	0,800	1
5	**Design complexity**	0,900	0,706	6
6	Complexity of construction method	0,900	0,631	18
7	**Improper coordination between different construction trades**	0,900	0,738	5
8	Additions to the original scope of work	0,880	0,663	15
9	Labor shortage	0,870	0,506	35
10	Poor conditions of tools and equipment	0,860	0,625	19

Results of the comparative analysis show that the findings of each study are different from the others. These dissimilarities prove that the factors affecting construction productivity change based upon geographical locations and different project types. However, there are some common factors observed among the studies.

Figure 29. Hong Kong critical factors comparison



6.4 PRODUCTIVITY RATE OF CRITICAL TRADES COMPARISON

Very few data on the productivity of the critical construction trades have been obtained for both regions Europe (1 questionnaire) and Hong Kong (2 questionnaires) because of the difficulty of obtaining such data from companies.

For this aspect, a comparison between both regions will not make, because these data are not representative due the size of both regions, the extreme quantity of companies working there and the few responses obtained. A comparison will not translate the reality and can lead to false conclusions.

CHAPTER 7. SUMMARY RESULTS, RECOMMENDATIONS

7.1 SUMMARY RESULTS

In today's world, the construction industry is rated as one of the key industry because of the many aspects that envelop. It helps in developing and achieving the goal of society. Study and knowledge of construction productivity are very important because they cause losses to the governing agencies and also influence the economics of the construction industry. Prior knowledge of labor productivity during construction can save money and time. Investments for these projects are very high and because of the complexity in construction, various factors can highly affect the overall productivity of the different construction trades, thus the project can end up adding even more time and money in order to be completed.

This research is intended to identify the critical construction trades and the factors affecting labor productivity of these trades for both building and infrastructure construction projects. This study investigates this through structured questionnaires administered all over Europe. The survey results are subjected to analysis, and the ranking of both critical construction trades and the factors affecting their labor productivity are calculated using the Relative Important Index.

Thirty-seven (37) construction trades based on the Construction Industry Council (CIC) of Hong Kong were selected for the study. The target groups in this study were construction professionals. A total of 22 questionnaires in both online and hard copy format were returned, most of them with a vast experience in constructions.

Forty (40) factors affecting the labor productivity of the critical construction trades considered for the study were categorized into six different groups. The target groups for this case study were construction professionals, and a total of 32 questionnaires in both online and hard copy were returned.

Additional comparisons with a study of the same kind did by some Hong Kong colleagues were made. The purpose of these was to improve the productivity of the most critical construction trades for Europe by mixing the results of both regions. The comparisons are based on the effects of the most critical trades of Europe in Hong Kong, according to the following criteria: total cost, labor shortage and automation level; for both building and infrastructure construction projects. A final comparison of the factors affecting the critical construction trades labor productivity for both regions was made.

7.2 RECOMMENDATIONS

Construction operations are expensive and frequently cause in arguments and claims, which generally affects the progress of construction projects. Mentioned below are the recommendations which were found on the research analysis for improving labor productivity in the construction industry in the Europe case.

i. To take care on the following 10 major construction trades for infrastructure projects: tunnel worker; prestressing operative; aspahlter (road construction); concrete and grouting worker; drain and pipe layer; fire service mechanic; metal-steel worker; marine construction plant operator (lifting); paving block layer; and, welder.

ii. To be attentive on the following 10 major construction trades for building projects: welder; electrician; prestressing operative; asbestos abatement worker; piling operative; hand-dug caisson worker; woodworker; metal-steel worker; marble worker; and, electronic equipment mechanic.

iii. To take special care with the common critical trades for both type of projects: welder; prestressing operative; and, metal-steel worker.

iv. Related to the labor shortage for building projects, seven of the critical construction trades need to be improved because of their high shortage level, being these: welder; electrician; prestressing operative; asbestos abatement worker; piling operative; woodworker; and, marble worker.

v. For building projects, improve the automation level of six of the critical construction trades: asbestos abatement worker; hand-dug caisson worker; woodworker; metal-steel worker; marble worker; and, electronic and equipment mechanic.

vi. Related to the labor shortage for infrastructure projects, seven of the critical construction trades need to be improved because of their high shortage level, being these: tunnel worker; prestressing operative; concrete and grouting worker; drain and pipe layer; and, metal-steel worker.

vii. For infrastructure projects, improve the automation level of three of the critical construction trades: fire service mechanic; marine construction plant operator (lifting); and, paving block layer.

viii. To take special care into the following two group factors, which took the highest weights between the six groups factors, and almost the 50% of the total weight: changes/errors in the original scope of work and complexity of the works; and, poor resource plan and logistics.

ix. To carefully analyze the ten most critical factors affecting the labor productivity of the critical construction trades: design changes, errors and omissions; communication problems between management and workers; poor qualification/experienced of management at different levels; shortage of skilled/experienced workers; improper coordination between different construction trades; design complexity; unclear technical specifications; unfavourable economic and financial conditions; inappropriate construction method; and, lack of training/orientation program for workers.

x. Throughout the mixing of both Europe and Hong Kong regions, based on the Europe critical construction trades for building projects. To be attentive in the critical Europe trades having a low cost, a low shortage level and a high automation level in the Hong Kong results. The construction trades having in common the previous points are the following three: asbestos abatement worker; hand-dug caisson worker; and, marble worker.

xi. To take care of the same as the previous point (x.) but for infrastructure projects. The construction trades having in common the previous points are the following three: drain and pipe layer; fire service mechanic; and, marine construction plant operator (lifting).

xii. Based on the Europe critical factors affecting the labor productivity of the critical construction trades, we look which one between them have a low importance into the Hong Kong case, being these: communication problems between management and workers; poor qualification/experienced of management at different levels; shortage of skilled/experienced workers; unfavorable economic and financial conditions; and, lack of training/orientation program for workers.

7.3 FUTURE RESEARCHES

The current research has been limited to find the most critical construction trades for both infrastructure and building projects and the most critical factors affecting the labor productivity of the overall construction trades found previously. This is just the beginning of a search that could focus on more aspects, such as:

i. See in which levels affect the previous critical construction trades in specific projects such as skyscrapers, highways, bridges, etc. and just not in general projects such infrastructure and buildings, as did.

ii. Analyze how each of the critical factors affecting the labor productivity affect one by one the critical construction trades.

iii. The research was focused in a vast region as Europe, it would be a good idea to focus country by country in order to satisfy their proper productivity needs.

iv. To find more representative productivity data of the different critical construction trades.

v. Most of the previous analysis were limited to only the ten most critical construction trades for both regions. Future papers can focus not just on them, but in the overall construction trades.

REFERENCES

[1] Construction Productivity in Turkmenistan: Survey of the Constraining Factors; *International Journal of e-Education, e-Business, e-Management and e-Learning, Vol 3, No. 1, February 2013;* Serdar Durdyev, Syuhaida Ismail and Nooh Abu Bakar.

[2] Improving productivity in construction; *The Safety & Health Practitioner, November 2012, ProQuest, page 63.*

[3] 10 steps to improving construction productivity; *Plumbing & Mechanical, January 2013, ProQuest page 72*; Adrian James J.

[4] Measurement of input-specific productivity growth with an application to the construction industry in Spain and Portugal; *Int. J. Production Economics 166 (2015) pages 64 to 71*; M. Kapelko, I.M. Horta, A.S. Camacho and A. Oude Lansinnk

[5] Mechanical and General Construction Productivity Results; *AACE International Transactions, 2011, ProQuest pg. CS71*; Daryl L. Orth and Dr. James L. Jenkins.

[6] A system for monitoring and improving construction operative productivity in Nigeria; *Construction Management and Economics, 2004, pages 175 to 186*; P.O. Olomolaiye and S.O. Ogunlana.

[7] Construction Productivity Measures for Innovation *Projects; Journal of construction engineering and management, May 2013, pages 670 to 677*; Jan Bröchner and Thomas Olofsson.

[8] Industrial Engineering in Improving Construction Productivity; *Proceedings of the 2010 Industrial Engineering Research Conference*; J. Fowler and S. Mason.

[9] An analysis of construction productivity in Malaysia; *Construction Management and Economics, December 2014, pages 1055 to 1069*; Fah Choy Chia, Martin Skitmore, Goran Runeson and Adrian Bridge.

[10] Improving construction productivity: a subcontractor's perspective; *Engineering Construction and Architectural Management, Vol. 21, No. 3, 2014, pages 245 to 260*; Martin Loosemore.

[11] Towards the smart construction site: improving productivity and safety of construction projects using multi-agent systems, real-time simulation and automated machine control;

Proceeding of the 2012 Winter Simulation Conference; C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose and A.M. Uhrmacher.

[12] Construction industry productivity and the potential for collaborative practice; *International Journal of Project Management 32, 2014, pages 315 to 326*; Richard Fulford and Craig Standing.

[13] A review of enabling factors in construction industry productivity in an Australian environment; *Construction Innovation, Vol 14, No2, 2014, pages 210 to 228*; Rami Hughes and David Thorpe.

[14] Towards improving construction labor productivity and project's performance; *Alexandra Engineering Journal, March 2012, 50, pages 321 to 330*; Mostafa E. Shehata and Khaled M. El-Gohary.

[15] Improving site productivity in the construction industry; *International Labour Organisation of Geneva 1987;* Alan Heap

[16] Managing Productivity in Construction, Just-In-Time operations and Measurements; *Published by Ashgate Publishing Company, 1997;* Low Sui Pheng and Chan Yue Meng.

[17] Construction Productivity Management; *Addison Wesley Longman, 1998;* Paul O. Olomolaiye, Anando K.W. Jayawardane and Frank C. Harris.

[18] Productivity Improvement in Construction; *McGraw-Hill Book Company, 1989;* Clarkson H. Oglesby, Henry W. Parker and Gregory A. Howell.

[19] Factors Affecting Construction Labor Productivity, managing efficiency in work planning; *Intergraph Corporation, 2012*; Integraph Corportation.

[20] A Study on Labor Productivity in Construction Industry; *Civil Engineering Department, Patil Institute of Engineering and Tecnology of Maharashtra, India*, *January 2016*; Sudam Chavan and Hemant Salunkhe.

[21] Key Factors Affecting Labor Productivity in the Construction Industry; *Thesis presented in the University of Florida, Science in Building Construction, 2007;* Casey Jo Kuykendall.