Multiskilled labor force: a discussion of this missing link of lean construction in Brazilian companies

Mão-de-obra polivalente: uma discussão desse elo perdido da lean construction em empresas brasileiras

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Abstract

Multiskilled labor is a ubiquitous concept and its adoption is suggested in various production approaches such as sociotechnical systems, cellular arrangements and, most notably, related to Lean Production, as it provides flexibility to the work environment. This research work aimed at identifying the extent of the use of multiskilling in a sample of Brazilian construction sites. A survey was conducted comprising variables such as reasons for simultaneous use of specialized and multiskilled labor. A total of 191 valid questionnaires were returned. Statistical analyses point out that it is common to employ both specialized and multiskilled labor in the majority of sites. Furthermore, multiskilling and subcontracting are concomitant flexible strategies to accommodate labor provision on site. The share of multiskilling is greater than reported in academic works, the number of skills is as restricted as in literature propositions and the size of the building firm is determinant of the share of multiskilled labor in the total workforce. This research work concludes that: work flexibility may be obtained with different strategies (multiskilled; specialized and multiskilled; subcontracting); employing only specialized trades is not a dominant culture on building sites.

Keywords: Building sites. Multi-skilled workforce. Specialized labor. Size of building sites. Multiskilling. Subcontracting. Work organization.

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Resumo

Polivalência é um elemento sugerido em várias abordagens de produção, como a produção enxuta, pois promove flexibilidade. Esta pesquisa objetivou identificar o alcance da polivalência em uma amostra de obras brasileiras. Um questionário foi aplicado buscando levantar variáveis como razões para a simultaneidade entre especialistas e polivalentes, com um total de 191 respostas válidas. Análises estatísticas apontaram que é comum o emprego simultâneo de polivalentes e especialistas na maioria dos canteiros. Além disso, polivalentes e subcontratados compõem uma estratégia concomitante para prover flexibilidade. A propoção de polivalentes é maior do que em outros estudos, o número de habilidades em polivalentes corrobora com a bibliografia e o porte da empresa é determinante para essa proporção em relação a toda a mão de obra. Essa pesquisa concluiu que: a flexibilidade pode ser obtida por diferentes estratégias (polivalência, especialização e polivalência, subcontratação) e empregar apenas especialistas não é uma prática dominante nos canteiros de obras.

***Palavras-chave**: Canteiros de obras. Polivalentes. Especialistas. Tamanho dos canteiros de obras. Polivalência. Subcontratação. Organização do trabalho.*

Introduction

One of the greatest challenges faced by all industries is fitting labor skills to job demands (NASIRIAN; ARASHPOUR; ABBASI, 2019). In the Fordist era, the division of labor was structured around a production line. In Taylorism, specialized and best-fit workers were central concepts (CROWLEY *et al*., 2010; SOUSA; SANTOS, 2017). During the 1950s, work division and production systems were strongly affected by lean production concepts and efficiency improvements reached unprecedented levels. Toyota, for example, increased profitability after the implementation of its production system aiming at waste reduction, changing old labor arrangements (*e.g*., high specialization in job allocation) and replacing them with innovative practices (OHNO, 1978). Production systems of the automobile industry were strongly impacted by the insertion of lean production concepts, taking the efficiency of this industry to a new level (WOMACK; JONES; ROOS, 2004). Ohno (1978) studied automotive factories operating in the 1940s and found that the idea of an operator working on many different types of machines was already at that time a cornerstone for the optimization of factory resources. Ohno (1978) noted that the main obstacle was the traditional mentality focused on the specialization of the workforce, which means that the factory needed as many different workers as different machines that were in operation.

About fifty years later, Koskela (1992) proposed an adaptation of *lean* production concepts to enhance efficiency in the building construction industry. Koskela (1992) indicated how lean principles could be implemented in the construction sector, e.g., aiming at reducing non-value-adding activities, variability, and cycle time, while increasing output flexibility. Multiskilling was encouraged as it goes in line with such aims. A reduction in the number of process steps and parts would also help to decrease demands on different operatives' skills. In parallel, some authors proposed multiskilling adoption in construction sites, as reviewed as follows. Notwithstanding, this early association between both concepts, multitasking and lean practices have been taken as separate strategies (BAYRAKTAR *et al*., 2011).

Multiskilled labor, according to Burleson *et al*. (1998, p. 480), is a kind of workforce with operatives "[…] unrestricted by traditional job descriptions or work boundaries […]", *i.e*., able to work on tasks related to different professions within the same project. An example of multiskilling is an individual who can works as a carpenter and also as a bricklayer. This paper is focused on multiskilled labor as an individual characteristic of single workers, but this concept can embrace also multiskilled workgroups.

Furthermore, there are other strategies for workforce flexibility like subcontracting. According to Jungles (1980), subcontracting is used in specific services or to cope with growing labor demands. Notwithstanding, Melles (1997) reported examples of Dutch housing construction companies which increased efficiency when the subcontracted workforce was replaced by multiskilled workgroups. The same author indicated that full implementation of multiskilling has led to radical changes in organization and that some companies did not have the "attitude to accomplish these innovative undertakings".

More recently, authors like Nasirian *et al.* (2022) devoted their research effort to multiskilling. These authors conducted a simulation with data for an off-site construction factory to define a better model for workforce allocation. Barkokebas, Al-Hussein and Hamzeh (2023) also studied multiskilling in off-site construction factories, especially in connection to the reassignment of a multiskilled workforce in a digital twin environment.

As demonstrated by Pereira (2003), on the other hand, there are construction companies that argue in favor of specialization as a strategy. Single-skill workers or specialized workers have only one traditional job description and boundaries for what they are supposed to perform are clearly set. Their view is that specialists are more attractive to builders or subcontractors because they allegedly have better productivity and quality standards. In addition, Maia (1995) reported that an educational training program focused on multiskilling might be needed for its implementation, as it is not a concept that would emerge naturally on construction sites, through traditional on the job training.

Researches like Lima (1995), Dalcul, Oliveira and Ruas (1997), Pereira (2003) and Biesek (2008) have compared the alternative of use of specialists or multiskilled labor force. As they are based on small samples, conclusions are of little value, despite their methodological efforts.

Maturana, Alarcón and Deprez (2003), Korb *et al*. (2019), Nasirian *et al*. (2019a, 2019b, 2022), Korb and Sacks (2021) and Barkokebas, Al-Hussein and Hamzeh (2023) addressed multiskilling through simulation scenarios. They compare operational parameters such as work duration, productivity and final due dates imposing several theoretical quantitative attributes for multiskilled labor as compared to specialized one. The

actual evidence on these operational parameters is hard to find in practical terms, what confines this sort of research work to just a theoretical exercise.

Literature on the Brazilian state-of-the-art for multiskilling is controversial. Pereira's (2003) research highlighted that both companies and workers under investigation prefer specialization: companies because they faced bureaucratic difficulties when tasks are paid and workers because they preferred to choose their favorite jobs. On the other hand, Mutti (1995) took a view from the workers' perspective, stating that the availability of multiskilling opportunities is positive for operatives' professional growth. One of the first steps to pursue in this academic field is to assure that multiskilling is feasible and worthwhile as an operational strategy for the Brazilian scenario. Due to evidence raised up to the current date, further work can be directed to the synergy between multiskilling and other managerial stakes, such as lean construction, quality, productivity, motivation, labor satisfaction and quality of jobs offered by the construction industry.

As a macro strategy for the building sector, a number of different questions and variables are brought to the discussion. An ideal share of specialized and multiskilled labor might be investigated. Gomar, Haas and Morton (2002) studied the optimal ratio between multiskilled and specialists at construction sites, that present limits that may be broader or more restrictive (less proportion of multiskilled in mixed teams). Maia (1995) argued that multiskilling implementation needs professional education in a formal way. Moreover, specialized and multiskilling might be significantly different in terms of how extensive they might be.

Furthermore, on the applicability of multiskilled or specialized labor according to different subsectors of the construction industry, Nasirian *et al.* (2022) and Barkokebas, Al-Hussein and Hamzeh (2023) exemplify research work directed to off-site construction, while sectors like residential, commercial or infrastructure projects are still in need of greater academic efforts.

Within this context, the aim of this research was to identify the extent of the use of multiskilling and related variables on a sample of Brazilian construction sites. To fully attend this aim, specific aims were defined:

(a) to identify proportions between multiskilled and specialists' labor;

(b) to classify flexibility strategies and possible preemptions; and

(c) to characterize learning skill mechanisms under actual operation and their possible differences for specialized and multiskilled workforce.

Such specific objectives are suggested in the literature review; this is a relevant condition pointed out by Waslawick (2009) for the results' validity.

Literature review

Studies show that a number of operational variables are positively influenced by a multiskilled workforce. Construction management authors (MATURANA; ALARCÓN; DEPREZ, 2003; CUPERUS; WAMELINK; RESODIHARDJO, 2010; KORB *et al.* 2019) are in agreement with Ohno (1978) regarding the potential for resource optimization through the use of multiskilled labor. Yu *et al.* (2009) addressed the possibility of reducing lead time with multiskilling, as each specialized fragmented task leads to a different set of equipment and skills, avoiding the need of a greater number of employees. Work flow can be improved due to the fact that with a multiskilled workforce there are less transitions from one operative to the other and each worker takes on more tasks for a given work package (YU *et al.*, 2009).

Maturana, Alarcón and Deprez (2003) proposed a simulation model for the reduction of idle time, partially calibrating their data with actual site performance. The results indicated a 14 % decrease in the required workforce and a shorter construction time (6 % reduction) when using a 30 % multiskilled workforce instead of a team 100 % made of specialists. Korb *et al.* (2019) also used simulation but studied a low-income housing project in the US carried out by multiskilled workers. Reported time-savings with a multiskilled workforce were up to 27.2 %. Cuperus, Wamelink and Resodihardjo (2010) conducted a pilot project on Dutch dwellings, comparing specialized and multiskilled teams while working in the same housing construction design. With the use of multiskilling, the project duration was reduced from 35 to 11-19 days.

Sacks, Esquenazi and Goldin (2007) put forward research results on the application of multiskilling and lean construction to high-rise apartment buildings. The authors showed that multiskilling must be combined with other lean techniques such as pull flow and reduced batch size and a good workforce allocation method to achieve a time-cycle reduction and avoid the need for reworking. In addition, if multiskilling is not properly implemented, negative effects in terms of project cash flow may arise (SACKS; ESQUENAZI; GOLDIN, 2007).

Fini *et al*. (2017) and Hegazy *et al*. (2000) highlight the relation between multiskilling in labor allocation and project results, with positive effects such as better training of young workers in multiskilled teams and reduction in project delays when resources are scarce. When a workgroup has a mix of personnel, an important factor to be considered is the proportion of multiskilled to single-skilled workers (FINI *et al*., 2016). Gomar, Haas and Morton (2002) concluded that, regarding economic aspects of the use of mixed labor resources, proportions greater than 20 % of multiskilled workers generate only marginal benefits to contractors, and more than two or three crafts provide marginal benefits (in terms of salaries and productivity) for the operatives. According to Burleson *et al*. (1998), there are benefits (e.g., reduction in labor and project costs, increased employment duration, and others) associated with the adoption of dual-skill or four-skill-helper workers. Similar results have been reported by Nasirian *et al*. (2019a), who carried out a study on the use of multiskilling in simulations with different strategies applied to offsite construction. They found that two or three skill strategies would be similar to the four-skill-helper strategy, in terms of advantages or disadvantages. The authors also concluded that multiskilling is aligned with the ISO 9000 standard regarding investment in technical teams, because it provides professional growth. According to Mutti (1995) and to Dalcul, Oliveira and Ruas (1997), this professional growth is explained by the fact that this sort of labor remains longer in each construction site, avoiding dismissals and new hirings as usual in the building industry.

Hegazy *et al*. (2000) observed that only a few studies on simulation had been published at the time of their research. More recently, Nasirian *et al*. (2019a, 2019b) again explore simulation methods showing good comparative results in terms of productivity. The authors experienced with multiskilling in an Australian company that produced prefabricated modular bathrooms. In addition, Fini *et al*. (2018) recommended the use of strategies such as multiskilling to normalize problematic admissions/dismissals on building sites, as related to low-skilled inexperienced workers. Additionally, the correct allocation and composition of teams during the planning phase to achieve a multiskilling implementation success is paramount according to Haas *et al*. (2001). These authors maintain that site planning is different when there are only specialists or mixed teams (both specialists and multiskilled).

Adopting as a strategy at the building company corporate framework, multiskilling might be advantageous to offset variable demand at the contractual level as highlighted by Haas *et al*. (2001), again minimizing hires and layoffs as related to the whole company staff. On the other hand, Fini *et al*. (2017) cited multiskilling to solve skill demand problems within the company. The authors used simulation, and considered multiskilled workers in charge of formwork and concreting operation tasks.

Cell concepts are used in production processes in which workers are preferably multiskilled, being able to perform activities on different machines and equipment. The physical arrangement resulting from this approach provides more flexibility to the production system, and also reduces costs and production times. The use of the cell concept in construction and its association with multiskilling was addressed by Korb and Sacks (2021), through simulations, taking into account comparatively to the alternative recourse of subcontracting. Moser and Santos (2003) applied the manufacturing cell concept to the drywall construction process, with a multiskilling team, resulting in an increase in flexibility in terms of workforce allocation and a reduction in activities related to inspection. All members in a manufacturing cell have the knowledge related to the myriad of tasks that a cell is supposed to perform and they could not do more than only one function, and also help other employees in their activities and in quality control. Reductions in waiting times were also reported. Flexibility in workforce allocation is a characteristic of sociotechnical resilience (GERSONIUS; ASHLEY; ZEVENBERGEN, 2012; TANTRI; AMIR, 2019).

According to Leveson (2006), resilience is the ability of the system to adapt to circumstances, maintaining control over a property of the system. In the present research work, a system property might be production stability. i.e., availability of multiskilled workers could maintain building works in progress while specialists are unavailable.

Improved working abilities can be obtained by formal training (on the job or at educational institutes) or relying on the sharing of experiences among the labor force. Bogado (2010) highlighted the importance of training construction workers to achieve multiskilling. In his research study, the workforce was divided into two groups: experimental and control. The group that underwent training achieved a performance 11 % higher than the group without training for multiskilling. Financial savings associated with human resources reached 10 %. Contrasting this notable improvement in productivity and quality, training required an investment of less than 1 % of the total construction costs.

Lean thinking has the potential to reduce or even mitigate problems associated with the variability inherent to the construction industry. This variability is observed not only due to the project design, generally unique, but also due to clients' demands for customization, among other sources.

Changes in the design of housing units put an extra burden on planning and control of the building process. In this regard, Rocha, Kemmer and Meneses (2016) indicate that the restructuring of the work leads to the reduction of repetitive work lots and multiskilling can reduce the problems associated with the customization of housing units.

Despite the importance of using multiskilled labor to attend to the tenets of lean construction, it can be noted that few studies have been carried out to evaluate the application (reasons) or not (alternatives) of a multiskilled workforce in practical cases using samples with statistical validity. Simulation continues to be the main source of evidence on multiskilling advantages as pointed out by Cardoso, Abreu and Marchiori's (2019) systematic review. (78 % of multiskilling evidences are reported nowadays based on this methodological approach). Recent research efforts linking lean production and multiskilling are found in Maturana, Alarcón and Deprez (2003), Korb *et al.* (2019), Nasirian *et al.* (2019a, 2019b), and Korb and Sacks (2021).

A more encompassing view on the subject stems from different research approaches. Each method has assumptions, strengths and weaknesses (AZEVEDO *et al.*, 2013; TONG, 2019). Case studies like in Pereira (2003), result in creative insights and deep analysis of a specific context, but, according to Voss, Tsikriktsis and Frohlich (2002, p. 195) "[…] care is needed in drawing generalizable conclusions from a limited set of cases […]". Simulations have more control in experiments and their operationalization is faster than case studies, but their applicability depends on the availability of practical data input (MEDEIROS; MOSER; SANTOS, 2014). Research approaches apart case studies or simulation – such as statistical analysis on real data - may confirm or present new perspectives (AZEVEDO *et al.*, 2013; TONG, 2019) on multiskilling knowledge as applied to the construction industry.

Method

Firstly, a review was conducted, focused on production systems and lean construction. Afterwards, a systematic bibliographic review on building construction multiskilling construction was carried out using the method described by Botelho, Cunha and Macedo (2011).

The survey method is considered an adequate method for this research work because, according to Forza (2002, p. 155), "[…] data collection is carried out with the specific aim of testing the adequacy of the concepts developed in relation to the phenomenon, of hypothesized linkages among the concepts.". A study using statistical techniques (hypothesis testing with qualitative and quantitative variables) was carried out to understand the extent of use of multiskilling by building construction companies in Brazil. The research methodological steps are summarized in Figure 1.

The survey was designed as an exploratory study and deals with: research question proposition, survey design, questionnaire elaboration and pretest, data collection, quantitative and qualitative analysis. A research question indicates a survey design, encompassing two dimensions – measurement and representation (GROVES *et al.*, 2011). Measurement reports to variables and their relations in connection to the research construct – "extent of multiskilling adoption", while representation defines objects under investigation, namely the characteristics of construction companies in the sample. The following provides a description of variables, hypotheses, population, sample and data collection. Variables under investigation were classified according to Table 1.

Variables V1 to V6 gave rise to a questionnaire, including inquiries into building company size, number of multiskilled workers usually employed on a building site, use of subcontracting as a strategy, and qualitative aspects of decisions regarding multiskilling (an open question allowing participants to share their perceptions on multiskilling). An open question promoted better and enriched in insights.

Variables were suggested in multiskilling literature. The possibility of using simulation to evaluate possible managerial efforts by building companies was not deemed appropriate, according to what might be taken as the level of administrative sophistication for the majority of Brazilian firms. This follows Forza (2002)'s recommendation to adjust questions to what is deemed reasonable according to the respondent's level of understanding.

Figure 1 – **Flow-chart showing the research procedure used in this study**

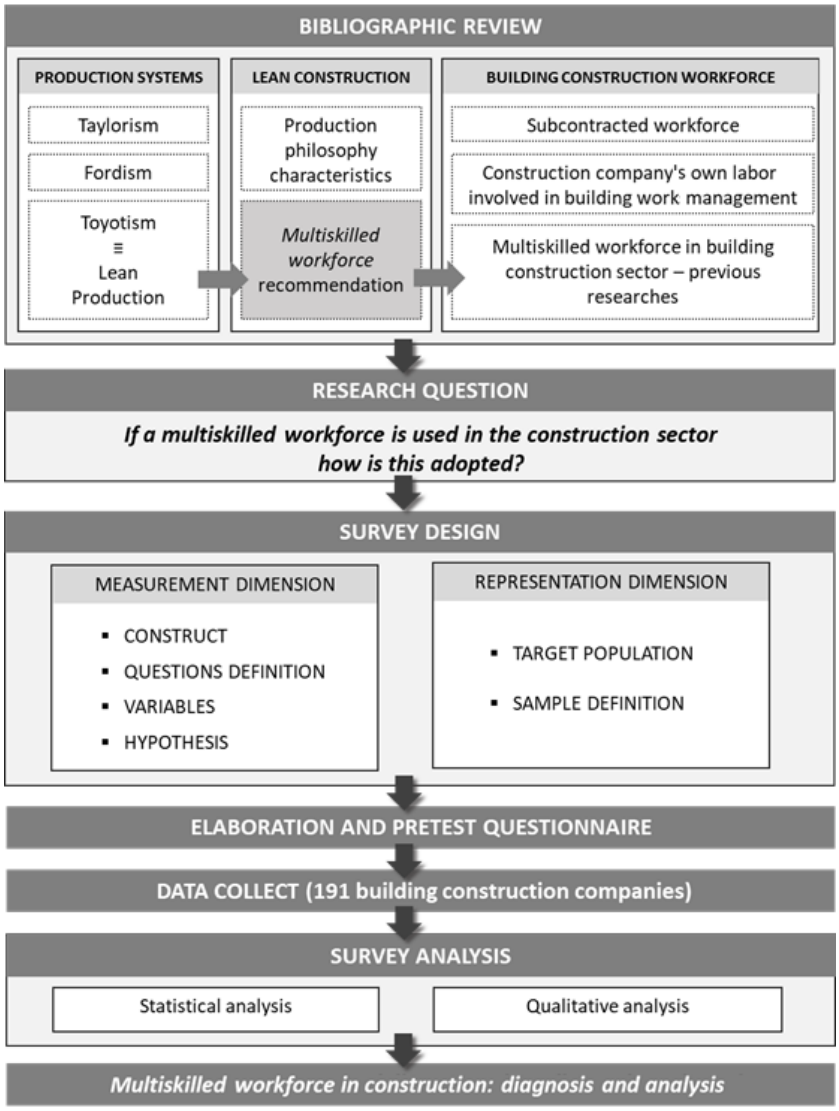


Table 1 – **Variables under investigation from sample characterization or literature review on multiskilling**

Classification	Variables	Notes
Company	V1. Sector	Collected to describe construction sector (residential, commercial, infrastructure…)
	V2. Average number of employees at building works	For sample characterization
	V3. Presence of subcontracted workforce	To define the presence of this flexibility strategy indicated by Jungles (1980) and Melles (1997) (This variable is related to the second specific aim)
	V4. Presence of a multiskilled workforce	Main research variable of interest
Employees	V5. Proportion of multiskilled workforce in mixed teams	To verify this proportion, because Gomar, Haas and Morton (2002) highlighted the optimum proportion of 20 % of multiskilled workers. (This variable is related to the first specific aim)
	V6. Learning mechanisms for professional skills development	For sample characterization and possible comparisons between specialists and multiskilled workers.

Prior to asking for a careful appreciation of questions on scrutiny, a multiskilling definition was produced based on Burleson *et al*. (1998). Emphasis was given to operational labor, unlike Sarihi, Shahhosseini and Banki (2020) and Shahbazi *et al.* (2019), whose work and questions deal with managerial staff. A non-probabilistic sample was used and respondents received the questionnaire link via messages in professional social networks (Linkedin). Prospective respondents must work as site managers or supervisors, and are supposedly acquainted with the labor force. Architects and engineers related to design teams were excluded from the sample.

Prospective respondents were first approached using a search string following the pattern: "Professional + city"; professional = "civil engineer", "architect", "industrial engineer"; city as Brazilian state capitals like "Porto Alegre" or "Salvador". A snowball method was further used to obtain a satisfactory sample size, according to Freitas *et al*. (2000).

"City" was employed in order to have a representative sample of different Brazilian regions. Complementary checking about the sector of each company, its size and geographical spread of work in regional terms was conducted through data scrutiny in public repositories and companies' websites.

The questionnaire remained open from November 2019 to September 2020. After removing blank or uncompleted questionnaires, duplicated, and possible inconsistent attitude towards thoughtful answers, 191 questionnaires were taken as valid out of 248 returns. Research objectives and its protocol were analyzed and approved according to ethical procedures demanded by the university hosting this research effort.

Statistical analysis of the average percentages was then carried out along with hypothesis testing (Table 2) using the software Microsoft Office Excel. The 191 sample provided a large enough number of cases to guarantee results statistical validity. Statistical saturation, as proposed by Freitas *et al*. (2000) and Forza (2002) was also taken into account. The first author suggested samples of between 100 and 300 cases while the second proposed a range between 170 and 400 elements as probabilistically yielding the same results as the 191 sample. Notwithstanding, randomness criterion, as indicated the last author, was not investigated, due to the still scarce number of valid cases for this statistical task.

Respondents' qualitative remarks were analyzed in order to draw additional insights on multiskilling usage. Research results were then discussed according to the literature review.

The sample composition is shown in Table 3.

Table 2 - **Hypothesis testing about multiskilling**

Kind of test	Hypothesis	Notes
Association of qualitative variables (Chi-square test)	H_0 = there is no association between how manpower was hired (own or own+subcontracted) and professional skills (specialist or multiskilled) H_1 = there is an association between these two qualitative variables.	Pereira (2003) indicated that multiskilling and subcontracting are exclusionary, than, these hypothesis considered a possibility of association of own workforce and multiskilling. This test could not be carried out because there were less than ten companies with only own workforce.
Linear correlation (Student's t-test)	H_0 = there is no correlation between percentage of multiskilled and average number of employees in building works and H_1 = there is correlation.	Size of a construction company and quantities of work could affect multiskilling demands, according to Maia (1995). Number of employees was taken as a proxy for building company sizes (BRASIL, 2020).
Difference between two average numbers (Student's t-test)	H_0 = average proportions of multiskilled in residential construction subsector (RES) and commercial-industrial-infrastructure construction subsector (CIIN) are similar and H_1 = these groups are different in terms of average proportions.	Aragão and Pequeno (2020) highlighted differences between building/civil construction subsectors that could affect multiskilling usage.

Table 3 – **Sample characteristics**

	Categories	Frequency	Percentage [%]
Respondents[a]	Architect	11	5.76
	Civil Engineer	115	60.21
	Industrial Engineer	11	5.76
	Director	23	12.04
	Owner	19	9.95
	Other	30	15.71
Company size[b]	Micro-company (up to 9 employees)	16	8.38
	Small company (10 to 49 employees)	67	35.08
	Medium company (50 to 99 employees)	38	19.90
	Large company (more than 99 employees)	70	36.65
Company sector	Residential	141	73.82
	Commercial-industrial-infrastructure	50	26.18

Note: [a]the results could be over 100 % since some respondents were classified in more than one category (e.g. Civil Engineers and Building Construction Owners). These percentages were calculated using 191 sample elements.
[b]company size is defined in Brazil according to the number of employees (not only those involved in building work positions but in administration and management positions, excluding subcontractors).

Results

Multiskilling as a percentage of the workforce

A significant amount of Brazilian construction companies have multiskilled workforce (Figure 2). In this sample, 36.13 % employed only specialists and 63.87 % had mixed teams composed of specialists and multiskilled workers. In companies with mixed teams, the proportions of employees who were specialists and multiskilled workers varied significantly; the average being 35.61 % multiskilled. Differences are significant for companies in residential construction (RES) and commercial-industrial-infrastructure (CIIN) with 33.02 % and 41.21 % respectively. These percentages illustrate a statistically significant difference, shown by a hypothesis test between two average numbers, based on the Student's t-test (t = -50.25 < t critical = -1.98, 118 degrees of freedom, a significance level of 5 %. The null hypothesis of non-difference between two average numbers could be rejected). Thus percentages are significantly different. Multiskilling was on average greater than the 20 % threshold indicated by Gomar, Haas and Morton (2002). Survey results also contrast with Yu *et al*. (2009): the majority of companies (Figure 2) were composed by mixed teams.

These values represent average percentages, but the proportion of multiskilled building construction employees in each company varies widely, as shown by the high dispersion in Figure 3 (considering only companies with multiskilling).

There is a tendency towards a reduction in the multiskilling rate when the number of employees on site increases. A linear regression model was proposed with a Pearson correlation coefficient (r) of -0.30. It confirms this reduction but indicates a weak linear relation. On testing the hypothesis of a linear correlation, the null hypothesis of non-correlation could be rejected (Student's t-test, t = -38.17 < t critical = -1.98, 117 degrees of freedom, significance level of 5 %). Thus correlation exists and deserves further investigation.

Linear regression models were tested using the transformation of the dependent variable (percentage of multiskilled *P*, in decimal format) and independent variable (number of building works employees *N*). The best-linearized models ($r^2_{adjusted}$ criterion) obtained using Infer32® software are shown in Equation 1 (linearized form) and in Equation 2 (non-linearized form):

$$ln(P) = -0.09534 - 0.3426ln\,(N) \quad \text{Eq. 1}$$

$$P = e^{-0.09534-0.3426ln\,(N)} \quad \text{Eq. 2}$$

The dispersion graph and tendency line for the best-linearized regression model can be seen in Figure 4. This model has a high dispersion. Statistical analysis results for this linearization are given in Table 4.

Figure 2 - **Multiskilling percentages in Brazilian construction companies**

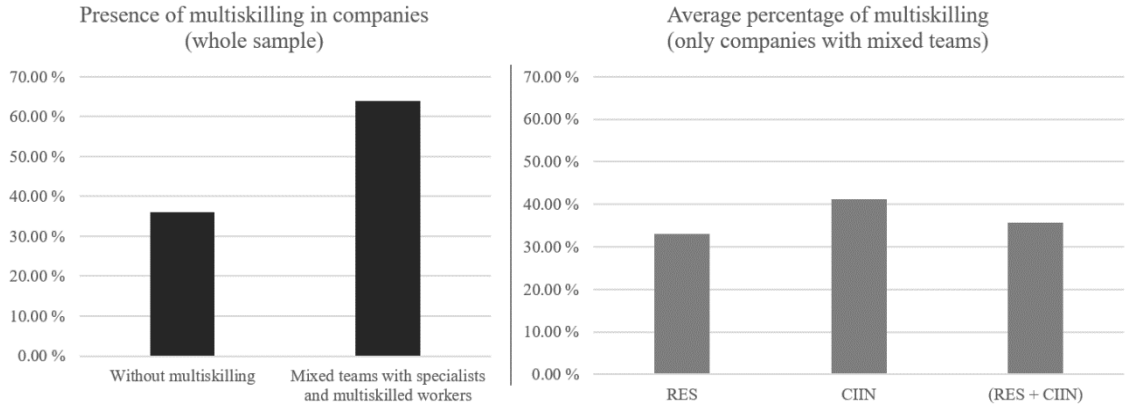


Figure 3 - **Percentage of multiskilled versus total number of employees involved in the building work positions**

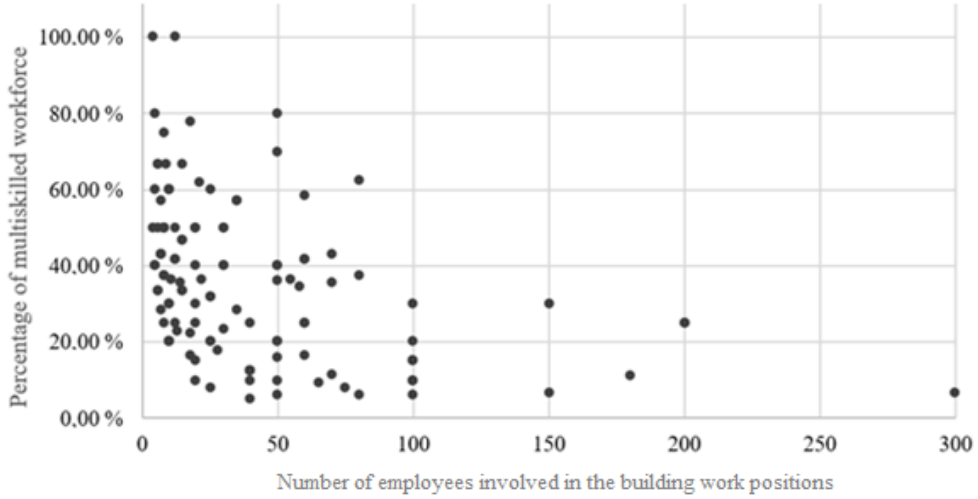


Figure 4 - **Dispersion graph of ln (P) x ln (N) for the best linear regression model**

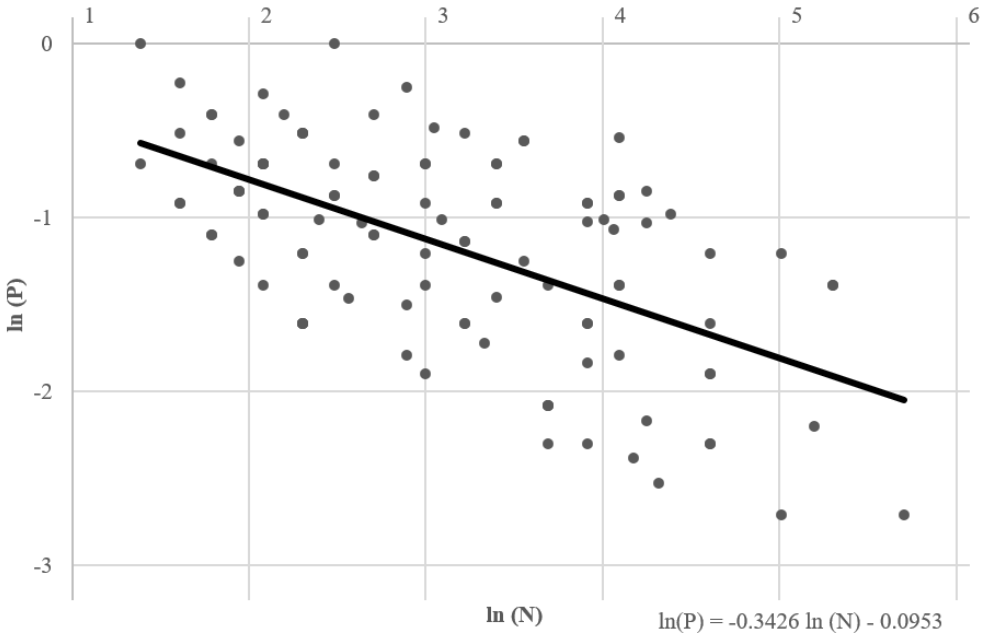


Table 4 – **Linearization statistics**

Statistical characteristic/test	Description
Sample and outliers	Nine outliers were removed (points over -2 or 2 standard deviations), and 110 data points[a] were adopted.
Influential data points	Cook's distance does not show this kind of points, all below 1.00.
F-test of variance	F-calculated: 55.58, F for the significance of 1 %: 6.876. Null-hypothesis of non-regression was rejected
t-test of regression coefficient significance	t-calculated: -7.455, t-critical: 1,6591 (two-tailed test): the null hypothesis of regression coefficient as zero was rejected. There is a statistical regression among variables.
Homoscedasticity	This was verified from a graph of residuals x estimated values – residuals do not show tendencies, i.e., verifying homoscedasticity.
Normality of residuals	In the Kolmogorov-Smirnov test, D-calculated = 0.0769 and D-critical = 0.1554: the null hypothesis of non-normality was rejected, i.e. the residuals have a normal distribution.
Autocorrelation	Residuals do not show tendencies, *i.e*. there is no autocorrelation, according to graph inspection.

Note: [a]data from companies with multiskilled workforce only, hence only 110 data points.

Pearson correlation coefficient (r) of -0.5829 for the linear model in Equation 1 indicates a moderate linear relationship between variables. Apparently, larger building construction companies have more repetitive work for single-skilled workers, but this is not sufficient to fully explain the level of multiskilling due to data dispersion.

Flexibility strategies

A different flexibility strategy is subcontracting, according to Jungles (1980) and Melles (1997). A large number of companies, 75.92 %, employ both their own and subcontracted labor. Just 15.18 % operate solely with subcontractors, while 8.90 % employ exclusively their own labor (employee-owned companies).Table 5 clarifies these statistics.

According to Table 5, subcontracting and multiskilling are strategies adopted in parallel, with the greatest number of companies in the sample adopting these two flexibility strategies in the production process. It was not possible ascertain the share of specialist and multiskilled labor for those companies reporting the use of only subcontracted labor. Moreover, it was not possible to provide meaningful statistics (Pearson Chi-Squared Test) comparing the share of specialist and mixed labor arrangements for those that either employ only own labor and own plus subcontracted one. This is due to the small number of employee-owned companies. Qualitatively, regardless of the presence or absence of subcontracting workers, the majority of the companies have a mixed workforce comprising specialists (single-skilled) and multiskilled workers.

Learning mechanisms for working abilities development

Most companies had workers with only informal training job experience, as shown in Table 6.

This data indicates that possibly both single-skilled and multiskilled workers have acquired their abilities based on job experiences with very little formal training. It was not possible to attest that multiskilled workers, employee-owned or subcontracted operatives, or different company sizes are associated with larger proportions of formal training. This is due to the small proportion of training (32 + 10 cases), which prevents further statistical analyses through data splitting between categories.

However, it can be said that, as expected, formal training is not common and might not be associated with larger proportions of work characteristics, like multiskilling, specialist, employee-owned or subcontracted labor in the Brazilian construction industry.

Qualitative analysis: benefits/disadvantages in multiskilling adoption

Respondents provided qualitative information on the use of multiskilled operatives, comprising a total of 136 insights for 191 questionnaires. In what follows, insights were classified according to Figure 5.

Table 5 – **Subcontracting versus multiskilling in Brazilian construction companies**

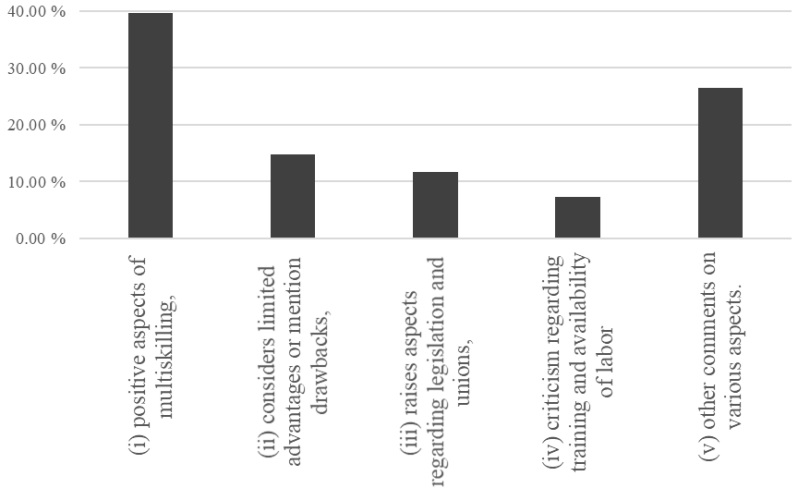
Workforce		Count	Percentage [%]
Own	Specialists (single-skilled)	4	2.09
	Mixed (specialists + multiskilled)	13	6.81
Own + Subcontracted	Specialists (single-skilled)	65	34.03
	Mixed (specialists + multiskilled)	109	57.07
Sum		191	100.00

Table 6 – **Where the job skills were learned**

Categories	Frequency	Percentage [%][a]
Formal building construction company training	32	16.75
Training from other companies or educational institutes (SENAI or other job training courses)[b]	10	5.24
Know-how from building works experience	167	87.43

Note: [a]the results could be over 100 % because some answers were classified in more than one category. The percentages are calculated using 191 sample elements.
[b]SENAI is the Brazilian Service of Industrial Learning, a private educational group providing industrial/technical training centers.

Figure 5 – **Frequency of insight categories**



Positive aspects for multiskilling usage, were addressed in category (i), comprising 39.71 % out of 168 insights. Workers might face better employability, since smaller companies or construction works, do not have jobs for a large number of specialists for long periods. Multiskilled workers also promotes flexibility in the production process, allowing adjustments and coping with the lack of professionals due to absenteeism. Furthermore, survey participants related quality and good work performance due to multiskilled mastering of their different jobs. These are associated with a restricted number of different abilities, a fact that corroborates the recommendation in the literature of two to four competencies per professional.

Multiskilling contributes to job retention and development of workforce skills both through employers' view, as stems from this research work, but also from the operative's points of view. According to Karakhan, Gambatese and Simmons (2020) multiskilling contributes to job retention and development abilities, corroborating with results of category (i).

Shortcomings or drawbacks regarding the use of a multiskilled labor force were analyzed according to category (ii), comprising 14.71 % of the total number of insights. Some employers question the quality of the services provided by multiskilled employees or believe that productivity might be better with specialists through the learning-effect process based on repetition. The limits of promoting flexibility in the allocation of labor is also mentioned in this category, notwithstanding the fact, as mentioned just by one respondent, that in the case of building maintenance and renovation (not included in the sample studied) flexibility of work allocation would be imperative.

Category (iii) accounts for 11.76 % of comments, relates to legislation and unions, which might be taken as a barrier to the greater adoption of multiskilled workers. Companies with a share of multiskilled labor do so without a legal framework, because there is no, as yet, such professional category supported by legislation. Labor building regulations do not allow deviations from a workers' preregistered function. According to Tavares (2015) and Araújo (2016), function deviation occurs when a worker is constantly performing a function for which he/she is not registered. This can generate differences in remuneration and even compensatory legal action, which has led to of concerns as expressed in the questionnaires.

On the other hand, the companies that use multiskilling make the point that legislation is illogical, because a construction site has many more different activities that the number of building operative categories that are officially listed at present. Modernization of the current labor legislation, with the inclusion of a suitable broad functional category, could offer legal safeguards to companies that adopt multiskilling, and allow the increased use of these professionals in companies concerned with employability.

The qualitative comments of the category (iv) correspond to 7.35 % of the answers, with criticisms related to the availability of labor and training. As presented in the previous section (Table 6), the training of Brazilian construction workers is based on site experience (87.43 %). This data corroborated with Mello and Amorim (2009) about the low level of formal qualification of Brazilian workforce, in comparison with other places like Europe or United States.

Many respondents pointed out that there is not enough qualified labor to take over activities of more than one functional category. However, according to Srour, Kiomjian and Srour (2016), the choice of whether to implement multiskilling is a strategic decision made by the companies; i.e., it is not necessarily associated with (iv) lack of training for multiskilling or other issues covered by categories (i – positive aspects of multiskilling), (ii – considers limited advantages or mention drawbacks) and (iii – raises aspects regarding legislation and unions).

Other noteworthy comments, although less frequent, can be found in the category (v – other comments on various aspects). One remark explores work organization for commercial store renovation in shopping centers during night shifts, with different activities most of them in small quantities. Due to the lack of space and difficulties in providing continuity of work for specialized labor, small teams made off multiskilled staff is the proper work organization to face the difficulties of this sort of assignment. Moreover, group work provides support for the lack of usual daylight shifts supervision and ease of information gathering. This idea corroborates the concept of sociotechnical resilience presented by Leveson (2006), where the system can adapt itself to situations and unforeseen events, in this case through the human and technical abilities of a multiskilled work force.

Qualitative remarks were addressed to possible links between multiskilling and lean construction, this latter concept mastered through word-of-mouth acquaintance or incipient practice by site managers. Survey questions did not mention specifically lean as a building production approach, thus those remarks might be taken as spontaneous view on both concepts' synergy. One director of a construction company mentioned the association between lean construction principles and multiskilling, due to his prior knowledge on the subject gained during training and in the course of professional activities. He stressed the need for changes in the national scene in order to promote multiskilling as a support to production improvements. According to him, lean construction is a possible strategy for a better construction industry. On the other hand, a number of respondents did not mention such possible relationship, even though they were in the course of applying lean principals and tools to their projects.

Discussions and implications

Multiskilling concepts and variables associated with their application have some key issues, part of them explored throughout this research work.

First, a bibliographic review was performed in order to know how this labor force management approach has been adopted over time in the construction industry. Initial concerns to be further clarified through literature are related, for example, to how far multiskilling spread as a common practice on building sites, as it now a long standing theoretical concept. Moreover, multiskilling might be taken as comprehensive domain of several building skills as craft based industry would require or just the development of one or two different abilities still in the field of work specialization. Site management might be faced with the extra burden of dealing with different work arrangements on their building sites, like when simultaneously employing specialist, multiskilled labor, own and subcontracted gangs or simplifying their administrative duties by employing just

one kind of work arrangement. At the industry level, either individual companies or institutions might formally support training or reinforce the informal spread of knowledge from worker to worker: in either case, specialist, multiskilled or both kinds of apprenticeship might deserve greater attention.

Literature reveals that in the international scene, multiskilling was evaluated in individual sites, mostly through simulation, even though first notes on their practical use might be traced back at least to Melles (1997). Brazilian research efforts concentrated in case studies ranging to six building companies (or building sites) at a time. This research work took a sample of almost two hundred building companies.

Research results indicated that multiskilling has been introduced over time (or was already previously adopted), as now more than 60 % of respondents stated a mixed labor force approach, including both multiskilled and specialist workforce on construction sites.

A flexible strategy, using simultaneously both multiskilled and specialist manpower should be carefully taken as an alternative, avoiding its exclusionary and preemptive as inferred by previous research work like Pereira (2003).

This research work found that multiskilling comprises a total labor force share of between 30 to 40%, what denies Gomar, Haas and Morton (2002) proposition that greater than a 20 % multiskilled workers have low benefits for companies. Notwithstanding, results demonstrates that this share varies from company to company and decreases as the size of the company increases. It remains to be investigated how different shares either help or hinder better operational performance in building projects.

Qualitative remarks pointed out that an excessive number of skills might be associated with worst workmanship and there should be, for most workers, a limited number of skills to be successfully incorporated to own's array of competences. This corroborates with Gomar, Haas and Morton (2002) and Burleson *et al.* (1998) suggesting the range of skills to be mastered by the workforce to be limited (dual-skill up to four-skill-helper workers).

On the job informal training is dominant. Most probably too much cannot be expected from this unstructured learning mechanism to get an adequate a multiskilled labor force, as cited by Maia (1995).

The craft character of construction tasks, appointed by respondents, is a barrier to the adoption of multiskilling. The level of industrialization must be much higher, in order to have better results in multiskilling implementation. Multiskilling would be associated with multispecialization in a non-craft based industry, if this is the way construction industry development would pursue.

Finally, multiskilling (and also specialization) approaches could not be traced back to any work structuring model like Taylorism, Fordism or Lean Production. Less than 1 % of questionnaires replies made such connection. As far as multiskilling and lean production goes, it seems to be a missing link as noted by Borges (2018). This author did not consider multiskilling as a positive indicator of lean management applications in building companies. According to him, that multiskilling is opposed to a specialist approach to labor employment, as dictated by Taylorism/Fordism, but is not associated with a more robust academic discipline, like Lean Production or Sociotechnical systems.

Conclusions

This research positively points out that multiskilling is currently being adopted in the construction industry in Brazil. On average, its share on total building site workforce is connected to the amount of labor employed: the larger the work force, the smaller the share of multiskilled labor and greater the amount of specialist one.

Despite being able to model multiskilled labor as a proportion of total manpower, on average results indicated a larger proportion than deemed suitable in the literature. This is to say that findings indicated as positive the presence of multiskilling, but it is necessary to investigate how it affects operational site indicators like the ones related to productivity and quality in new research venues.

While it does not get clear how this spontaneous presence of multiskilled labor affects the building industry and its initiatives to become more efficient, it is necessary to modernize labor regulations in order to safeguard companies adopting this labor organization strategy. Multiskilling should continue to be experienced until it becomes clear its advantages and shortcomings, but such experimental attitude towards different labor organization formats should not be hampered by legal considerations. It looks desirable to heap the benefits of multiskilling related to production flexibility and holding jobs for longer periods. On the other hand, this research work found that building companies without multiskilled workers maintain that specialists perform better in terms of productivity and quality, without the burden of increased training to master different skills.

Notwithstanding, additional training, formally through institutional arrangements or on the job, is constantly mentioned as a must needed input for better construction.

It is not the kind of labor to be initially addressed, specialist or multiskilled, that is at stake, but a larger investment, as a whole, in building a new construction workforce. Although the respondents did not make explicit the link between multiskilling and the lean construction philosophy, it is envisioned that the lean construction and sociotechnical initiatives to labor organization are natural environments for an in depth appreciation of multiskilling benefits.

As future work, it is suggested to propose guidelines to manage multiskilling workforce based on a mix of approaches highlighted in the literature (lean, occupational safety and health, among others). In addition, based on the knowledge pointed out in this article, that the construction market already makes use of multiskilled labor alongside specialists, future research may indicate the best arrangement regarding work organization (own or outsourced labor; multiskilled in varied services and specialists in those with repetition), providing supposedly flexible arrangements of the workforce.

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