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MECHANIZATION OF CONSTRUCTION TASKS: LEVEL ASSESSMENT AND CRAFT WORKFORCE AWARENESS

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ABSTRACT

Construction Industry (CI) tasks often consist of manual work and work-machine systems. Still, the craft workforce is the primary site labour dimension. Construction tasks are mainly artisanal and low productivity is one of the CI main concerns. There is a gap in craftwork modelling methods and a lack of research on construction tasks mechanization assessment. This work quantitatively assesses four on-site tasks' mechanization level through modelling the crew processes using work sampling and Monte Carlo methods. In addition, craft workers on duty dressed up wearables and through interviews delivered their impressions about electronic monitoring and task's mechanization.

INTRODUCTION

The trends towards Construction 4.0 suggest the increased involvement of digitalization and automatization. Human craft workforce is the industry's primary productive force and new monitoring methods can bring relevant outcomes for overall productivity, constituting therefore an important research topic. In addition, tasks with a higher level of mechanization achieve more significant output indexes (Hwang et al., 2019).

In what relates to the work routines at construction sites, two main vectors of innovation can be highlighted. These are electronic performance monitoring (digitalization) and efficiency improvement through the employment of tools, machines, and equipment (mechanization/robotization). Hwang et al. 2019 emphasizes that the measurement of the level of mechanization of tasks performed by construction workers is vital. Increasing mechanization on-site boosts productivity and may mitigate the current lack of available craft workforce (Hwang et al., 2019). Also the adoption of industrialised construction is increasing to support CI fast deliverables (Cao and Hall, 2019).

Naturally, countries with a high degree of development and labour shortages will actively implement robotization processes, precisely in the quest to reduce the need for human resources (Farmer, 2016). In contrast, countries where labour is available and cheap, robotization processes and tasks mechanization may not be economically viable. Despite tasks mechanization and robotization, labour electronic monitoring processes will become more and more a reality in developed countries. Craft workforce electronic performance monitoring also makes sense in developing countries, due to the pursuit of increasing competitiveness, safety and lower production costs (McKinsey, 2017).

Within the current construction framework, even in activities with a high degree of mechanisation, operators' presence is indispensable (Calvetti et al., 2019). In fact, craft workforce performance is the primary productive factor in the construction industry (Calvetti et al., 2019). Most construction tasks are based on worker-handed or worker-machines systems and few processes are based on automated systems (Groover, 2007). In this respect, worker-handed tasks are those developed only with human strength and technical skills or supported (efforts attenuated in some cases) through the use of hand tools (e.g. wrench, hacksaw, trowel) (Groover, 2007), portable power tools (e.g., drills, circular saw, routing tools) or other accessories. In other cases, the workforce operates machines/equipment (e.g., crane, backhoe, walk-behind vibratory-plate compactors) producing a worker-machines system.

According to Hwang et al. (2019), there is a lack of academic research on the assessment of mechanization in building construction projects (Hwang et al., 2019). Hwang et al. (2019) proposed a mechanization index assessment tool for projects based on a detailed analysis of the tools and by measuring the qualitative survey's level value. It is undoubtedly vital to measure the level of mechanization of construction tasks (Hwang et al., 2019). Strategic documents highlight that CI is handmade with little use of machinery and equipment; however, little is measured and known (Farmer, 2016; McKinsey, 2017; Hwang *et al.*, 2019). In addition to measurement, it is crucial to understand how the mechanized work is inserted in the production processes chain (Hwang et al., 2019). Simple mechanization might not guarantee high performance; the productive context of the crew can either enhance or decrease this. As an example, it is relevant to know how many crewmembers will support the work of a machine.

Additionally, knowing if these workers can carry out activities in parallel or whether they should wait for/follow-up the mechanical processes are, from a production context point of view, critical elements. In this respect, the proposed concept of measuring the mechanization level is derived primarily from a useful measurement in the field, considering all the processes of the crew involved.

EXPERIMENT

Processes Modelling and Mechanization Level

The research assesses the mechanization level of typical on-site construction tasks as (i) masonry in a residential building, (ii) masonry in a commercial building (iii) piping in public water supply infrastructure and, (iv) ETICS, External thermal insulation composite system, in a residential building.

The craft workforce motion productivity framework, namely Worker 4.0 Motion Productivity (W4MP), establishes nine processes to map and measure performance (Calvetti et al., 2020). Through this model it is possible to model any on-site construction task. The processes are characterised as (i) Operation, (ii) Inspection, (iii) Delay and, (iv) Transportation/Storage), follow the same pattern of well-known Process Chart Flow applied in macromotion studies (Meyers and Stewart, 2002; Groover, 2007). The processes based on the W4MP method are:

- Robotic automation, RBA (Operation - performing work dealing part of a product), e.g. robotic bricklaying arm
- Free-hand performing, FHP (Operation), e.g. placing a brick
- Manual tools, MNT (Operation), e.g. using a trowel
- Electric/Electronic tools, EET (Operation), e.g. using a drill
- Machines operation, MOP (Operation), e.g. using a bench circular saw, using a backhoe
- Auxiliary tools, AUT (Inspection - performing quality control work), e.g. using a spirit-level
- Carrying, CAR (Transportation/Storage - moving products and used for long-range storage), e.g. walking carrying something on hands as products
- Walking, WLK (Delay - waiting time, no work progress advance), e.g. walking without carrying anything on hands as going to the WC
- Do not operating value, IDL (Delay), e.g. doing no productive work. That does not effective contributes to the progress of the tasks, for example, planning, searching, chatting and, resting

Based on the Worker 4.0 Motion Productivity (W4MP), it is possible to quantitative measure the mechanization of the tasks conducted by the craft workforce (Calvetti *et al.*, 2020). Equation (1) presents the W4MP Mechanization index (Calvetti *et al.*, 2020). The model measures the proportion of the three mechanized processes (EET + MOP + RBA) concerning only the Operation processes. It without considering the other processes Inspection, Delay, and Transportation/storage. Evaluating the postulated equation results, based on the status quo of CI tasks, a classification scale was proposed (Calvetti *et al.*, 2020), as following: Low - 0% to 20%; Moderate - 21% to 40%; High - 41% to 60%; Very high - above 61%.

$$W4MP\ Mech.\ index = (EET + MOP + RBA) / (FHP + MNT + EET + MOP + RBA) \quad (1)$$

Data collection and processing

In the work sampling methodology, the data is collected through the human observation randomly performed and stratified according to the set of process/actions pre-established (Meyers and Stewart, 2002; Groover, 2007). It is essential to point out that this method is based only on the number of observations made, not requiring time-taking or any other verification. It should be noted that by increasing the number of observations recorded there is a direct relation with the confidence limit as well as with the reduction of the modelling error limit. Most of the time, the studies that apply the work sampling methodology use a 95% confidence limit and bound the error limit into a 5% accuracy (Meyers and Stewart, 2002).

The number of observations in each variable is transformed into a percentage value based on the total observations ratio. According to Meyers and Stewart (2002), the minor proportional item (process/action) in the analysis should indicate the sample size (Meyers and Stewart, 2002). For example, for a 95% confidence and 5% accuracy if the smallest element percentage is 1%, 152.127 observations are at least required.

Such large number of necessary observations to validate, from a statistical point of view, the analysis makes its execution very difficult, as the construction industry is based on projects with a beginning-end and not on continued processes as manufacturing.

The purpose of the data collection procedure was to detect workers' activities based on the Worker 4.0 motion productivity model. Observations are taken on a timely basis, whether or not timing is registered, assuring that the action marked is the one the worker performs at the very moment of the observation. During the data collection random observations of each worker's activity occurred in a time not less than three minutes for the same worker and by the same researcher.

The conducted analysis will first indicate the estimated ratios (proportion of each process). With the nine processes, a lower ratio on the smallest element in the analysis is expected, subsequently indicating a larger number of observations. For this reason, the collected samples will be statistically extrapolated through the Monte Carlo method, so that the distribution curves are evaluated, becoming redundant the static validation based on the sample size. This option was mainly given to the pandemic period (COVID-19) to mitigate the time spent in the on-site environment by external personal.

The proper calculations of the proportions based on the processes and their characteristics will be developed as well as the calculation of the W4MP Mechanization index. Monte Carlo method generates virtual data (pseudo-random numbers) from a sample of real data and may be used in different types of studies, for example, risk analysis (Calvetti *et al.*, 2018). The Monte Carlo technique was applied with the software @risk from Palisade Corporation. The Probability Distribution Functions obtained correspond to the distributions' sum, which represents each event's behaviour characterized by an analysis. In this case, the specific Probability Distribution Function represents the behaviour of each one of the nine processes considered to model the tasks. To determine each event's impact on the four tasks modelled process, after data modelling via Monte Carlo, the sensitivity analysis (tornado diagram) is developed. The Monte Carlo method was applied following these steps:

1. Data characterization and segmentation;
2. Suit the best Distribution Function for each process, considering Akaike adhesion test (AIC) and the percentage accuracy achieved;
3. Perform the Distribution Function determined for each of the nine processes for all the tasks;
4. Perform the Monte Carlo simulation for each task (sum of all the Distribution Functions of the nine processes) with 5000 interactions and 100 simulations;
5. Obtain and analyse the Probability Distribution Functions;
6. Obtain and analyse the sensitivity analysis (tornado diagram).

For the adoption of this technique, the distribution function curves considered are representing the behaviour of the modelled tasks, which corresponds to the sum of the distributions functions of all the nine processes that characterize them. However, the sensitivity analysis indicates which variables will have the most significant impact on the primary variable under analysis and are the most representative in the tasks' process. The Tornado Diagram presents in the "Y" axe and from a top-down vision the tasks that most impacted the distribution outcome. For the same analysis, the "X" axe represents the range of that impact around the baseline of the total sample (approximately 1.0), also colourful highlighting the low/high impacts measured. Finally, all tasks' distribution curves are confronted with the evaluation of the construction tasks' mechanisation level under analysis.

Interview

Interviews with craft workers were conducted during the on-site testing. These opened by explaining the purpose of using wearables sensing technology and asking open questions about their perception regarding the possibility of the Electronic Performance Monitoring and the Mechanization of the Work. These questions surrounded the following: (i) The prospect of being monitored for academic purposes and future similar monitoring by the employer, (ii) The benefits/threats of using this type of monitoring technologies and the mechanization of work.

DISCUSSION AND RESULT ANALYSIS

The modelling of each task is presented in a sequence followed by the calculation of each one's mechanization level. After that, an evaluation of all the distribution function and the mechanisation level results are carried out. Finally, the worker's interviews overall opinions are presented.

Masonry (Residential Building)

Masonry tasks were monitored on a residential building project. The internal partitions walls are built with blocks of expanded clay, and a silo supplies the prefabricated mortar. Only the brickwork was analysed (without coatings). In average, two to four craft workers were observed at once point of view. The crew was composed of three masons and an assistant.

The activities basically correspond to laying individual masonry units (expanded clay blocks 400x190x200mm, 15kg) with horizontal and vertical joints in mortar. It is necessary to measure the plumb/level of the walls. There is a demand for support services such as the mortar supply at the application sites, the cutting of some blocks into smaller pieces and the placement of a connecting frame between masonry and concrete elements.

Figure 1 graphically shows the classification relating their proportion based on the W4MP of the 3,484 observations made about the crew performance. It can be seen that the lowest proportion was the MOP - Machine operation (mortar pumping machine), not counting the Robotic automation not observed at all. Considering the sample's statistic validation in the work sampling methodology, the value of 2.87% indicates a sample needed of 52,000 observations (confidence level of 95% and an accuracy of 5%). As stated before, the Monte Carlo method will be applied to validate that small sample.

The modelling of this masonry process makes it possible to measure that most of the time (approximately 40%) the craft worker is handling a hand tool (mainly the trowel and the float with the action of laying mortar). In the sequence, the most systematic process is the free-hand performing (approximately 14%), which in most cases is the action of laying the blocks.

Approximately 64% of the time, workers are carrying out operations in a productive state. Most of the transports (loading) performed are the supply of mortar and blocks near the application sites. The workers carry out inspection activities to guarantee the plumb and level of the elements and the vertical joints' thickness. It should be noted that the block has a system that contains the vertical joint between two blocks in contact (providing even the false impression that it does not exist).

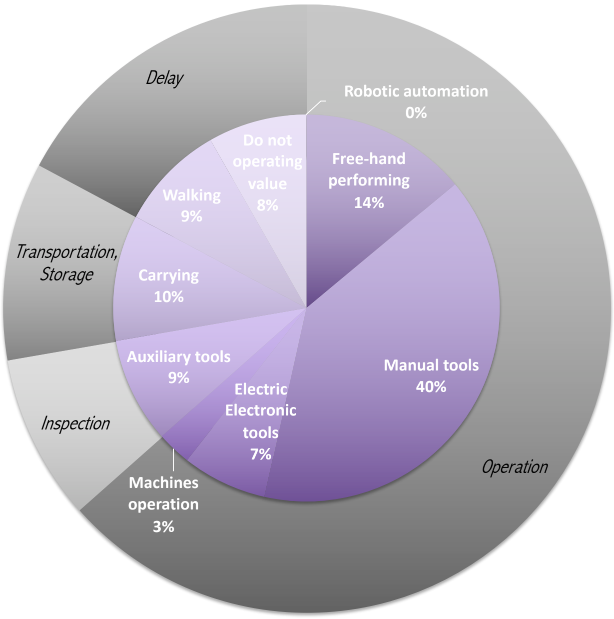

Figure 1: Masonry (residential) process modelling

The distribution most adequate to the task model was a logarithm normal (*lognorm*). As the probability density distribution is the sum of all processes distributions. The sensitivity analysis performed (Figure 2) indicates that most of the process impact in the output of the task modelled (input high), as respectively, (i) Manual tools, (ii) Free-hand performing, (iii) Walking, (iv) Carrying, (v) Auxiliary tools, (vi) Do not operating value, (vii) Electric/Electronic tools.

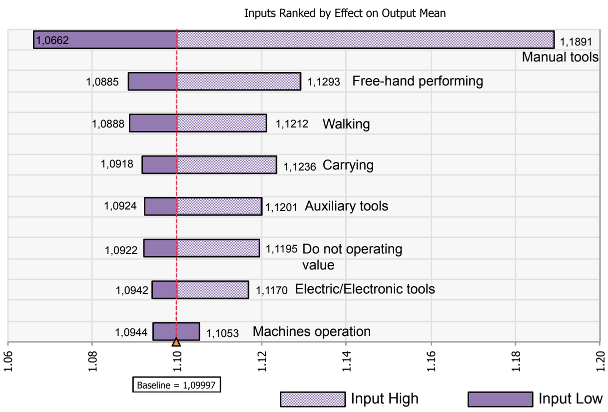

Figure 2: Masonry (residential) process sensitivity analysis

Equation (1) stated that the W4MP Mechanization index for that masonry task is 15.69% been considered Low in the scale proposed.

Masonry (Commercial Building)

Masonry tasks were monitored on a commercial building project. In this, the internal partitions walls are built both with blocks of expanded clay or concrete. The prefabricated mortar was supplied every day and stored in cubic containers (0.5 m^3 approximated). Only the brickwork was analysed (without coatings).

The crew was composed of three masons and an assistant. On average, two craft workers were observed at once point of view.

The activities correspond to laying individual masonry units (expanded clay blocks 400x190x200mm, 15kg, and concrete blocks 500x200x200mm, 14.6kg) with horizontal and vertical joints in mortar. In this project, the wall panels have big dimensions, 7 meters high and 7.5 meters long.

It is necessary to measure the plumb/level of the walls. As well, there is a demand for support services such as the mortar and blocks supply at the application sites. Also, the wall execution tasks demanded to cut some blocks into smaller pieces.

A forklift supplies the mortar and the blocks on the scaffolding elevation where the work was carried out. Drill and grinder are the electric tools used by the craft workers. Different manual tools and accessories are used (e.g., trowel, float, shovel, hammer, wheelbarrow). Also, auxiliary tools are used to measure position and verticality (e.g., level tool, tape measure).

Figure 3 shows the classification based on the W4MP of the 3,606 observations made regarding the crew performance. It can be seen that the lowest proportion was the AUT - Auxiliary tools with 3.85%, not counting the Robotic automation not observed at all. The modelling of this masonry process makes it possible to measure that most of the time (approximately 41%) the craft worker is handling a hand tool (mainly the trowel and the float with the action of laying mortar). This result is very similar confronting the 40% achieved in the residential masonry project presented in the previous sub-section.

In the sequence, the most systematic process is the free-hand performing (approximately 20%), which in most cases is the action of laying the blocks. That action was also the second action most measured in the other masonry task observed.

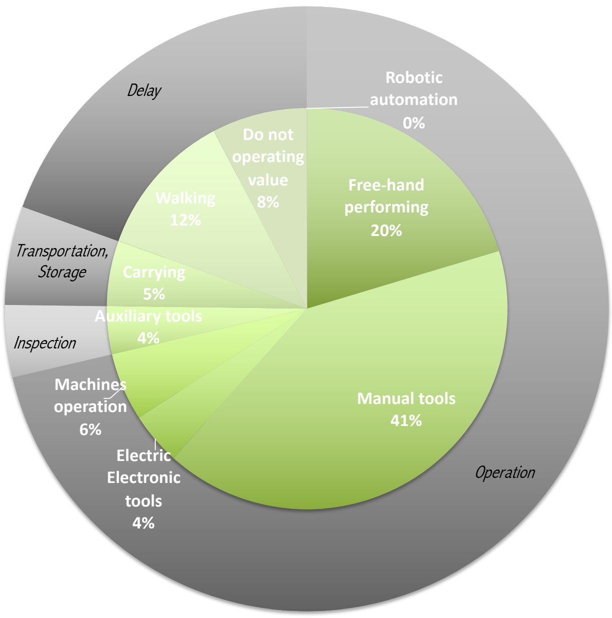

Figure 3: Masonry (commercial) process modelling

The adequate distribution to the task model was an inverse Gaussian (invgauss) called the Wald distribution. The probability density distribution is the sum of all processes distributions. The sensitivity analysis performed (Figure 4) indicates that four of the processes impacts in the output of the task modelled (input high), as respectively, (i) Manual tools, (ii) Free-hand performing, (iii) Walking, (iv) Do not operating value.

Finally, the W4MP Mechanization index, as stated on Equation (1) for that masonry task is 13.64% been considered Low in the proposed scale. As determined, the level of mechanization between masonry activities is approximate, both being classified as low. Which is not surprising given the high rate of manual work required for this process.

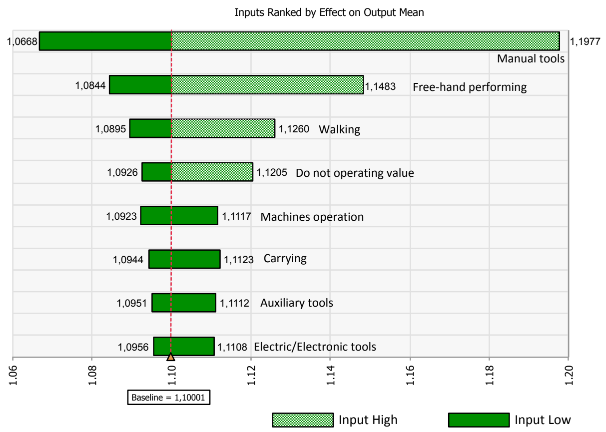

Figure 4: *Masonry (commercial) process sensitivity analysis*

Between the two activities evaluated in masonry buildings (residential and commercial), there is a remarkable similarity in the teams of workers' practical actions. Realize that due to the characteristic of smaller wall panels, the residential building work has more activities related to quality control (using auxiliary tools). This factor also influences the greater use of power tools (for cutting half a block) in the building residential worksite project. The distant location of the blocks and the need for a manual supply of mortar in the areas of use in the building residential work also influences a higher index of identified carrying actions. On the other hand, in the commercial building worksite, the support of the forklift indicated a more significant operation of machines, as well as it was observed that the workers walked more (also going up and down the stairs of the accesses of the scaffolding).

Piping (Water supply)

The work consisted of the requalification of the water distribution system for homes and commercial establishments within urban environment. The activities requirements and, the machines/tools applied will be detailed in the next section. Only the processes that each craft worker performs at the observed moment will be analysed for these activities.

In average, five to seven workers were observed at once point of view. The activities consisted of mechanized disruption of the existing pathway pavement, removal of this pavement, mechanical excavation and soil removal, placement of pipes and branches, backfilling, and mechanical soil compaction. In street services, the stone pavement and curbs were recomposed.

Based on 1,164 observations, the Worker 4.0 Motion Productivity (W4MP) was populated as presented in Figure 5. It can be seen that the lowest proportion was the EET (Electric/Electronic tools), not counting the Robotic automation not observed at all. It is observed that among the nine processes the most observed was the IDL (Do not operating) with 32.30%, followed respectively by MOP (Machine operation) 19.59% and MNT (Manual tools) 18.47%. After, WLK (Walking) 10.14% and FHP (Free-hand performing) 9.54%.

Low inspection rate is observed, as there few measurements are needed for this specific work execution. Since transport is mostly carried out by machines (operators), workers were mostly transporting their tools and accessories. The delay is primarily related to the time that other workers wait for the machines' actions (e.g., excavation), and the acts of walking along the service fronts. Finally, operations represent the highest rate of activity. In the sequence, it presented the determined values: Operation: number of observations (564) 48.45%; Inspection: number of observations (28) 2.41%; Delay: number of observations (494) 42.44%; Transportation/ Storage: number of observations (78) 6.70%.

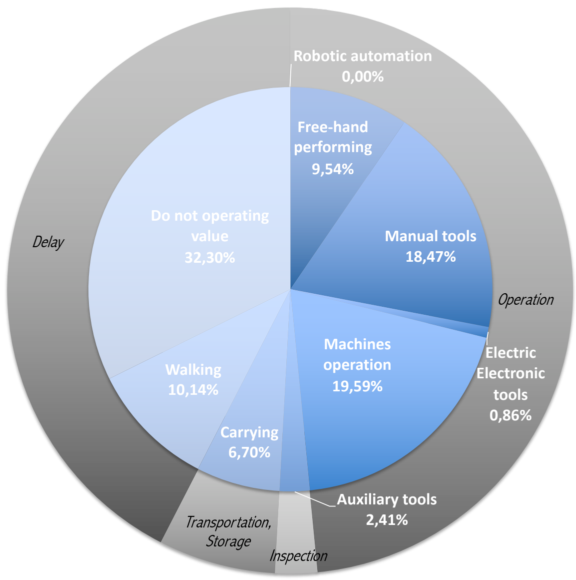

Figure 5: Piping (water supply) process modelling

The distribution most adequate to the task model was a triangular distribution (triang). As the probability density distribution is the sum of all processes distributions. The sensitivity analysis performed (Figure 6) indicates that five of the process impacts in the output of the task modelled (input high), as respectively, (i) Do not operating value, (ii) Machines operation, (iii) Manual tools, (iv) Walking, (v) Free-hand performing.

The W4MP Mechanization index for this piping task is 42.20%, being considered as High in the scale proposed. Simultaneously, piping activity reached a higher mechanization level than masonry activities, which was also expected given the mechanical excavations inherent in that piping tasks. Forward the results of the three experiments will be confronted and discussed.

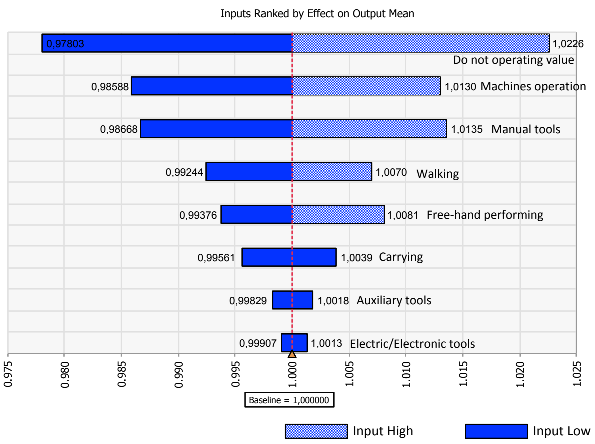

Figure 6: Piping (water supply) process sensitivity analysis

ETICS, External thermal insulation composite system (Residential)

A crew composed of two officials and an assistant performed the thermal insulation of exterior walls. On average, two craft workers were observed at once point of view.

The activities correspond to cutting and fitting the mineral insulation board, apply mortar to the entire surface, press on plate and float in, insert and plaster reinforcement mesh, and texture the finishing plaster. There is a demand for support services such as the supply of mortar at the application sites and cutting some boards into smaller pieces.

Figure 7 shows the classification based on the W4MP of the 314 observations made about the crew performance. It can be seen that the lowest proportion was the Electric/Electronic tools (mixing mortar), not counting the Robotic automation and Machines operation not observed at all. The modelling of this ETICS process makes it possible to measure that most of the time (approximately 45.5%) the craft worker is handling a hand tool, mainly the trowel and the float with the action of laying mortar, as well as, using a box cutter knife to cut and fit the mineral insulation board. In the sequence, the most systematic process is the free-hand performing (approximately 24.5%), which in most cases is the action of press on plate and float in. The most adequate distribution to the task model was an exponential distribution (expon). As the probability density distribution is the sum of all processes distributions. The sensitivity analysis performed (Figure 8) indicates that three of the process impacts in the output of the task modelled (input high), as respectively, (i) Manual tools, (ii) Free-hand performing, (iii) Do not operating value. Finally, the W4MP Mechanization index, as stated on Equation (1) for that ETICS task is 1.79% been considered Low in the scale proposed.

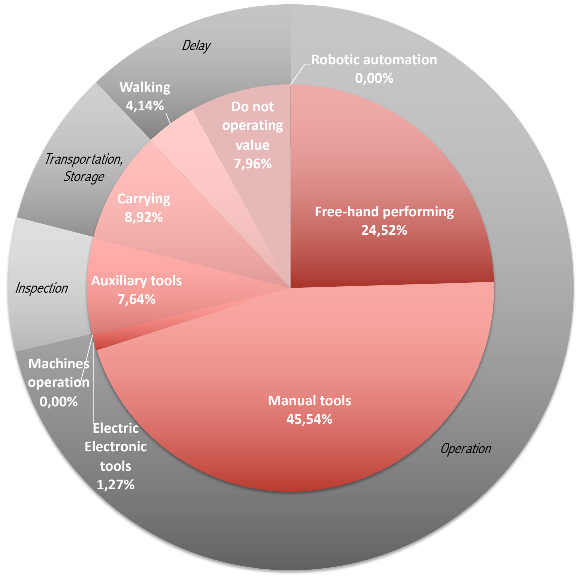

Figure 7: ETICS (residential) process modelling

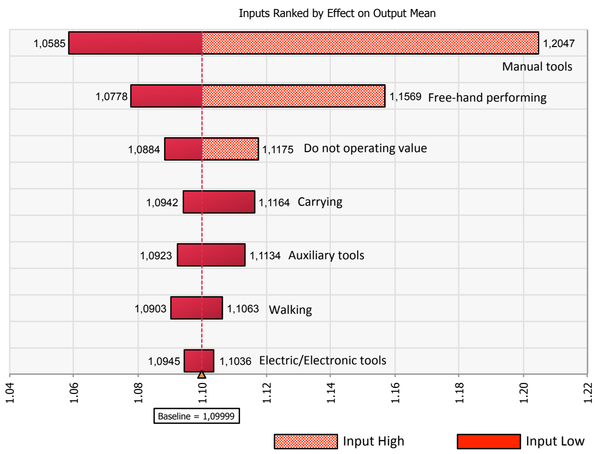

Figure 8: ETICS (residential) process sensitivity analysis

Mechanization Level

Figure 9 concentrates the modelled processes' results and the mechanization level of the four evaluated tasks through probability distribution functions. The Cumulative Distribution Ascending Curves represents the process of each task and has shown to be adequate.

As a result, it can be seen the similarity of Masonry tasks (both residential and commercial building), as well, the dissimilarity with the ETICS and culminating in a big difference for the piping task, which has a very different process from the others. The quantitative mechanization level measured is found to well represent the process of the tasks, being respectively for Piping in the water supply (42.20% - High), Masonry in a residential building (15.69% - Low), Masonry in commercial building (13.64% - Low) and ETICS in a residential building (1.79% - Low). As mentioned above, it is observed that each task achieved a condescending mechanization level based on their particular characteristics.

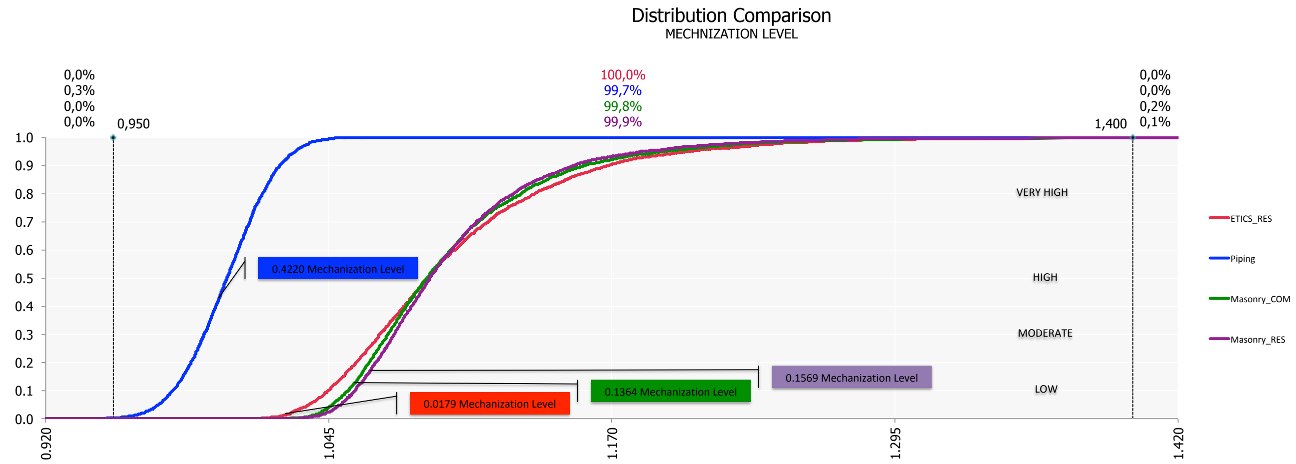

Figure 9: Cumulative Distribution Functions and Mechanization Levels

Significantly, it was measured that although the piping task has a high mechanization level, its operative level is lower than the masonry and ETICS tasks. From this highlights that an increase in the tasks level of mechanization might not be enough to obtain better productive results. As identified, by having some equipment in operation and several workers on delay (waiting for the equipment operation) the production process suffer negative impacts.

The modelling of production processes based on the teams' performance allows the identification of how the performance of each individual contributes to the overall tasks performance. Thus, the distortions related to the interrelationship of activities and the lack of synchrony between workers-workers, workers-machine, and even workers and other actors (e.g., inspectors, supervisors) can be assessed. For example, the modelling of that piping task allowed a close view of that work-machine process, making explicit a process failure. The layout assessment is crucial to evaluate/improve productivity (Nazarian *et al.*, 2018). Finally, the modelling of workers and teams' activities provides an improved level of knowledge regarding the production processes, indicating a more positive route for continuous improvement actions.

In the proposed W4MP (Worker 4.0 Motion Productivity), the mechanisation level assessment is integrated into the modelling of the task developed by the connected on-site crew (Calvetti *et al.*, 2020). As a result, the mechanisation level evaluation is made, taking into consideration the work system and how the full process may be improved to achieve the best outcome results.

Craft workforce awareness

In order to avoid any identification of the thoughts or opinions of the interviewed workers, no correlation to their functions/names is made. Some personal characteristics will be presented to illustrate the situation, avoiding however any direct reference.

The workers who already wore wristwatches indicated that they did not feel any discomfort when wearing the devices. In contrast, the other workers who did not wear watches in their day-to-day reported discomfort when wearing it; one of them mentioned that he would not use the devices due to this discomfort. The workers expressed significant discomfort regarding filming their actions. Physical reactions of inhibition were observed. Furthermore, a worker demonstrated verbal discontent with the footage, asking, "is it being posted live on the internet?". In general, the workers agreed to use the wearables for academic purposes. After being monitored on the first day, only one of them refused to continue using the devices and declined to speak regarding the reasons for doing it.

When faced with the idea of a future request/demand from the part of the employer to use the monitoring devices, the workers were generally vague, not directly answering the question. Even when the possibility of financial compensation was indicated, the workers did not want to commit themselves to any affirmation/denial. Only three workers said that would use the devices without any problem and that this would not have any influence at all. Two workers indicated health monitoring as a benefit. They stressed that the work requires a tremendous physical effort and that the expended calories control as well as fatigue would be relevant.

When indicated that these studies could better evaluate production processes, enhancing improvements, and increasing mechanization, one worker was effusively against any mechanization. In his words: "Mechanization is bad because it takes away our work. If there are more machines, we have less work, and that is bad". Even when it was argued that the machines are to assist the worker (such as an electric drill), this same worker maintained his position contrary to mechanization, encouraging his colleagues to agree with him on this position.

CONCLUSIONS

The research tested an approach for the quantitative assessment of construction tasks mechanization level. This approach used field observations of craft workforce performing tasks (collected manually by the team) as well as observations from on electronic wearables. As part of the experience worker's impressions were collected regarding the use of electronic monitoring devices.

The study suffered from a major constrain related with the access and continuous presence in construction sites due to the COVID-19. This led to a smaller tasks sample as well as to smaller observations number. This limitation was found to be an opportunity to strategically develop a generic methodology based on Monte Carlo simulations to achieve improved sensibility results based on the lower level of observations.

Several conclusions can be drawn from this study as follows: (i) From the experiments it becomes clear that the use of more equipment might not lead to improved productivity, (ii) There are several aspects that impact the productivity and these are related with the type of work, site conditions, crews, among others. This means that future studies must be performed to evaluate further these aspects and their relevance for the more or less productive environment on tasks development, (iii) The applied process modelling method is found to be a valid and strong component to support mechanization level assessments as well as crew approaches, (iv) Most of the interviewed craft workers revealed low awareness in terms of innovative actions on construction sites. Yet, few were quite aware of the potential and benefits of wearable devices, (v) The proposed methodology contributes to the body of knowledge of tasks processes modelling, by establishing assumptions that can be used by a wide range of stakeholders to collect information related with the same or other tasks, promoting the establishment and future disclosure of benchmarks.

Despite the outcomes there are several aspects that require future studies. As mentioned above, larger studies ranging more tasks, the same tasks under different condition and the same tasks in similar conditions but with a larger number of observations will allow an improved calibration of the methodology, higher knowledge on the variables that impact the processes, in which way more mechanization can lead to higher productivity and in what tasks and, finally, improve the sensibility regarding the application of the Monte Carlo simulation in the case of constraints or impossibility of large number of observations.

Given the dimension of the productivity issues in the CI and facing the relevance of craft workforce on-site, even in more developed countries, it is clear that in the sector roadmap towards sustainability there must be actions seeking methodologies for an improved measurement of the activities and through the use of electronic devices. Likewise, awareness and skills about innovative actions on construction sites are essential to foster transparency, added-value training and improved performance on tasks development.

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