Gamification technique for supporting transparency on construction sites: a case study

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Abstract

Purpose – The purpose of this paper is to evaluate the impacts of using gamification techniques to improve transparency of production assignments and worker performance and to increase the engagement of construction workers.

Design/methodology/approach – The research strategy is based on design science research. A web tool called Gamified Construction Project System was designed, implemented and evaluated through empirical studies.

Findings – The effectiveness of game mechanics used in the GamifiedSystem, such as the point system, the badge, the leaderboard and the feedbacks loops, improved the communication of weekly tasks, rules and policies through better information transparency; the system also motivated the workers to be more engaged and to improve their performance to win the game.

Originality/value – The main contribution of this study is the incorporation of gamification techniques in the visual management construction field and the adherence of the workforce to production tasks and rules.

Keywords Workforce, Transparency, Visual management, Gamification, Building construction, Last Planner System

Paper type Research paper

Introduction

With an increase in the adoption of Lean Construction principles, the importance of improving transparency and communication in the production processes has gained prominence (Koskela, 1992; Formoso *et al.*, 2002; Tezel *et al.*, 2010; Brady *et al.*, 2012, 2013). According to Formoso *et al.* (2002), process transparency is the ability of a production process (or its parts) to communicate with people. Therefore, information flow is an important concern (Koskela, 1992), requiring an improvement in communications among different areas of construction sites to ensure that the information reaches the right person at the right time and as needed.

Moreover, in the last few years, the construction industry has faced several changes that demand the development of innovative managerial solutions aimed at improving labor and material controls and an increase in communication. Within this context, the adoption of Last Planner System (LPS) in construction projects, which is a production control system for managing projects based on activities and defined schedules, has contributed to stabilizing the production process, maximizing value

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generation, eliminating the waste of overproduction (Ballard, 2000; Ballard and Howell, 2004), and also does indeed strengthen social network and communication (Priven and Sacks, 2015).

The literature review points out that lack of transparency and poor communication between the management levels (Alarcón *et al.*, 2005; Brady *et al.*, 2012, 2013), a workforce and low employee engagement (Han *et al.*, 2008; Arashpour *et al.*, 2012), unstable workflows (Arashpour and Arashpour, 2015) and quality issues causing rework (Love and Smith, 2003; Arashpour and Arashpour, 2015) are internal variables which hamper the effective achievement of weekly construction work plans.

Therefore, the elimination of noise and problems in communications is extremely important in an effective planning system (Brady *et al.*, 2012). For this, managers should seek dynamic forms, and even interactive ones, to assist in the information dissemination process. In addition, the workforce needs to adhere to the plan; information dissemination is not sufficient to guarantee that the plan will be understood, processed and followed (Grief, 1991).

In order to bridge this gap, visual management (VM) principles and gamification techniques can spur the development of innovative systems aiming better transparency and worker engagement. VM is a comprehensive strategy and a fundamental element of the Toyota Production System because it installs vital information as close to the point of use as possible and people can draw information from the system; this generates new levels of employee inventiveness and contributions (Ohno, 1988; Shingo, 1989; Grief, 1991; Galsworth, 2005). In the construction industry, VM has been studied mostly in the context of building construction; its concepts have been highlighted and an understanding of applications and the implementation of some practices and tools have been developed (Dos Santos and Powell, 1999; Heineck *et al.*, 2002; Formoso *et al.*, 2002; Moser and Dos Santos, 2003; Picchi and Granja, 2004; Kemmer *et al.*, 2006; Tezel *et al.*, 2010, 2015; Brady *et al.*, 2012, 2013; Valente and Costa, 2014).

In addition, VM takes supportive role in other managerial practices, serving a broad range of functions within an organization, particularly at the operational level (Tezel *et al.*, 2009). An example of functions of VM is transparency. VM when aligned with the gamification can leverage transparency since this association can contribute to increase communication and improve the engagement and adherence of the workers and the project management team.

The term gamification has been receiving accentuated attention. Although gamification may be a new term, the idea of using game thinking and game mechanics to solve problems and engage audiences is not exactly new (Zichermann and Cunningham, 2011), having its origin in marketing endeavors, such as points cards and rewards memberships, educational structures, most notably scholastic levels, grades, and degrees, and workplace productivity (Nelson, 2012).

However, little empirical work has sought to validate gamification as a meaningful concept and provide evidence of its effectiveness as a tool for motivating and engaging users in the non-entertainment context (Seaborn and Fels, 2015). Even though some elements of gamification have been on the scene in the construction industry for sometime now, those have not been systematically explored. By the time this study was conducted, no case study had been identified in the literature review that addressed gamification in the AEC industry. Therefore, the use of gamification techniques is a trend that can be adapted to the construction industry in specific situations to change the traditionalist approach in terms of engagement, communication and interaction between the employee and the project plan.

The main research question of this study is "how the gamification techniques can assist the transparency of production planning and worker performance, and the engagement of the construction workers?" Thus, a Gamified Construction Project System consisting of visual communication panels for the dissemination of weekly work plans and the exhibition of worker performance evaluations related to project policies was designed, implemented and evaluated based on empirical studies. This paper contributes to presenting the potential impacts of the use of gamification techniques for improving transparency of production planning and worker performance, and the engagement of construction workers.

Gamification techniques and VM

Deterding *et al.* (2011) summarize "gamification" as the use (rather than the extension) of; design (rather than game-based technology or other game-related practices); elements (rather than full-fledged games); characteristic of games (rather than play or playfulness); in non-game contexts (regardless of specific usage intentions, contexts or media of implementation).

Liu *et al.* (2011) suggests that the ultimate goal of gamification is to incentivize a non-game system user to have the so-called game-like behaviors, including focusing on the task at hand, multitasking under pressure, working overtime without a discontented attitude, and continuing to try when something fails. As yet, there is no agreed upon standard definition; likewise, there is little cohesion with respect to theoretical underpinnings and what gamification encompasses (Seaborn and Fels, 2015).

One of the most frequently leveraged frameworks of game design is referred to as MDA, which stands for mechanics, dynamics and aesthetics. The MDA framework is a postmortem analysis of the elements of a game. It helps us use systems thinking to describe the interplay of game elements and to apply them outside of games (Zichermann and Cunningham, 2011).

Mechanics are the decisions that designers – those who wish to gamify a non-game context – make to specify the goals, the rules, the setting, the context, the types of interactions and the boundaries of the situation to be gamified (Robson *et al.*, 2015). Those decisions need to be disclosed to the players; and in a construction site environment where digital means of communications are limited, VM can play and important role, allowing the designers to use visual elements to communicate.

Zichermann and Cunningham (2011) focus on seven primary elements: a point system, levels, leaderboards, badges, challenges/quests, onboarding and engagement loops. Points are important, and regardless of whether their accumulation is shared among players or between the designer and the player, they are an absolute requirement for all gamified systems (Zichermann and Cunningham, 2011). A leaderboard is also an essential game mechanic and its purpose is to make simple comparisons through a ranking system (Zichermann and Cunningham, 2011). Those game mechanics and structures are the essential building blocks of any Gamified experience.

The theory of gamification is deeply related to some psychological studies and human motivations. To understand player motivations, one must first question where motivation comes from. According to Zichermann and Cunningham (2011), broadly speaking, psychology has divided human motivations into two groups: intrinsic and extrinsic. Intrinsic motivations are those that derive from our core self and are not necessarily based on the world around us. Conversely, extrinsic motivations are driven mostly by the world around us, such as the desire to make money or to win a spelling bee (Zichermann and Cunningham, 2011). These authors suggest that designers should

consider both extrinsic and intrinsic motivation and use both monetary and non-monetary incentives.

A Gamified experience can be exemplified each time a user achieves a small goal and receives some reward, which is normally backed up by the point system (e.g. score, virtual currency or experience point). Based on the point system and an achievement history, a leaderboard (global or partial) and badges are provided to players for motivating competitiveness, which eventually results in a change in the players' virtual status in their social network or the system (Deterding *et al.*, 2011).

Aligning gamification with VM generates a synergic relationship. It is expected from a gamified situation to be visual and communicative and VM and it will help to engage the player into the game. At the same time, it is known that an efficient visual workplace requests an adherence of the parties to the information flow. Only the display of information does not mean that the communication is achieved. Thereby gamification can assist in the workers' engagement and this whole cycle drives to an increase in transparency in the construction site, which are essential elements of the flow understanding for construction production systems. The main association between VM as gamification can be seen from Figure 1.

Research method

Design science research also called as constructive research was chosen as the research approach because it is a form of scientific knowledge production that involves the development of innovative constructions, intended to solve problems confronted in the real world, and simultaneously makes a prescriptive scientific contribution (Lukka, 2003). This approach implies a very close involvement and cooperation between the researcher and practitioners in a team-like manner, in which experiential learning is expected to take place (Lukka, 2003). An artifact that solves a domain problem is an important outcome, which must be assessed against the criteria of value or utility (March and Smith, 1995).

Specifically in this study, the practical problem identified concerns the lack of transparency and worker engagement in weekly work plans. The artifact developed was the GamifiedSystem and the protocol for its implementation being those tested and validated through empirical studies. In addition, this study aims to provide a theoretical and practical contribution to the field of VM and gamification in construction.

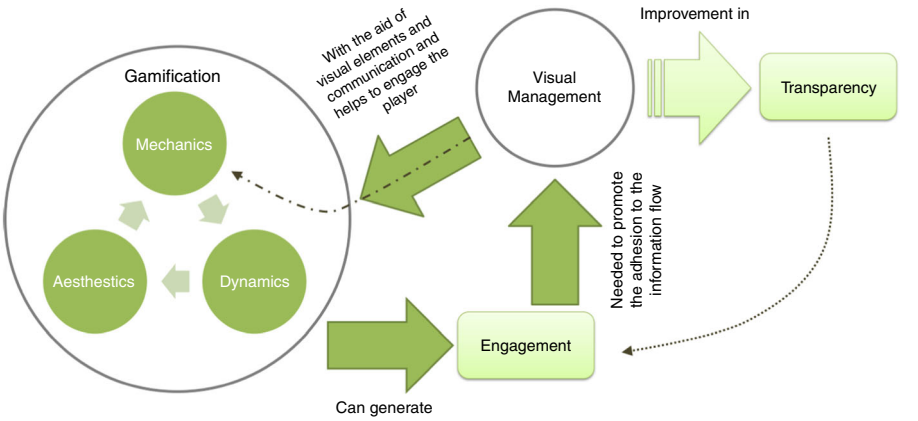

Figure 1.
Conceptual framework associating visual management and gamification

This study was developed along the following phases: (a) exploratory study, (b) development of the system, (c) implementation and review of the system, and (d) evaluation of the system, as shown in Figure 2.

Phases (a) and (b) were carried out based on Project A from Company 1, which involved the development and construction of a high-rise residential building in an affluent neighborhood in the city of Salvador-Bahia in Brazil. This project was selected because the third author of this paper worked as a junior engineer on this project, and he was also conducting this investigation as part of his undergraduate thesis. The findings from phases (a) and (b) were published in Morêda Neto *et al.* (2014). Thereby, this current paper focuses on phases (c) and (d).

Initially, the implementation of the Gamified Construction Project System in Project A was planned. However, due to a major schedule delay and changes in that project's management team, as well as the time limitation for the study, only the development of the system was based on that project. Therefore, a second project also from Company 1 agreed to be part of the study, so phases (c) and (d) were performed in Project B. The implementation in that project was possible since both projects had similar characteristics from the vantage point of construction methods, and managerial production systems such as production planning and control, quality control, and contractual agreement with the workers. Project B involved the development and construction of two high-rise residential towers in an affluent neighborhood in Salvador. In this project, the foreman, the crew leader, the safety manager, and the two junior engineers were part of the workers' supervision team.

Company 1 is a small to medium local real estate development and construction company in Salvador-Bahia, Brazil, and has a Quality Management System certified by ISO9000. The company had confronted a major increase in project demands from 2008 to 2012, encouraging them to implement basic last planner practices, create new managerial procedures, and use an Enterprise Resource Planning that integrates different areas such as finance/accounting, supply chain management, project management and construction management services, as examples of changes in managerial operations. For all these reasons, the top leaders agreed to be part of the study.

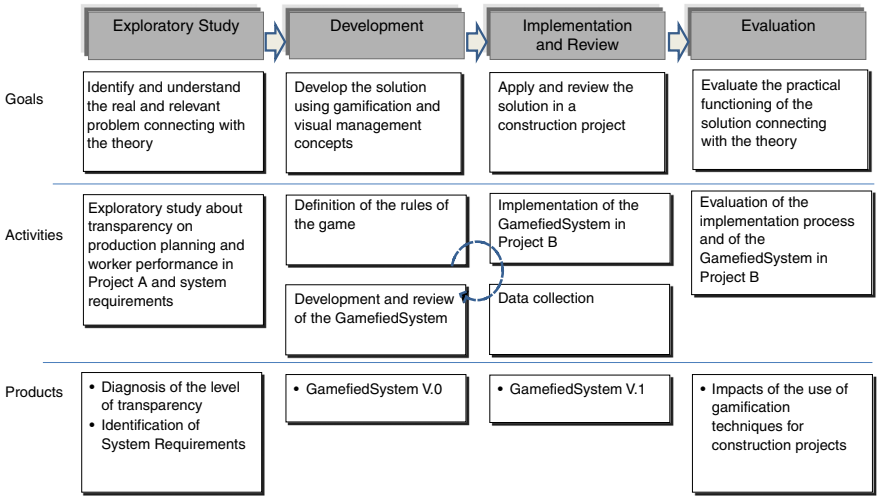

Figure 2.
Research design

Study development and data collection

As part of the design phase, the exploratory study investigated the level of workers' knowledge concerning the use of weekly work plans, highlighting the work plans' dissemination, feedbacks, work package accomplishments, and workforce self-assessment related to their motivation and commitment related to goals and company rules. Data were collected through a structured questionnaire in which 25 workers were interviewed (approximately 50 percent of the workers directly hired in Project A, selected in a simple random sampling). Two meetings involving the project manager and the schedule manager were also held to discuss the planning process in advance, and the involvement of the construction workers in this process. An additional six meetings were held between the researchers, the first and third authors of this paper, to identify the system's requirements.

The second phase involved the development of the GamifiedSystem, which aimed to conceive a game using visual panels for disseminating the weekly work plans and to establish team and individual workers' rankings, based on necessary activities and desired behaviors, such as completing the work assignment on time and with sufficient quality, cleaning and organizing, as collective rules, as well as following safety rules, and being involved in daily meetings (punctuality and attendance), as examples of individual rules. Together with the project manager from Project A, eight rules and a point system were initially established for the game. Specific worksheets for data collection concerning the rules were developed to be used during the implementation and to update system information. In addition, three game mechanics defined by Zichermann and Cunningham (2011) were used: a point system, a leaderboard and engagement loops. In the second version of the system, the badges mechanic was added.

Functional and non-functional requirements, the architecture of the system, the screen designs, and a diagram with a description of the system were created. Afterwards, a webmaster was hired to develop the system using a framework called Django, which follows the agile web application philosophy. The system was implemented in the Python programming language using a cloud service to store the database. From this stage, the Gamified Construction Project System V.0 was created.

The third stage involved the implementation and review of the System. Initially, the same structured questionnaire for the diagnosis of the level of worker knowledge was administered to 30 workers selected through simple random sampling, of which ten were workers from concrete pour subcontractor, ten workers were from formwork and rebar subcontractor, and ten workers were hired directly by Project B. At the moment of the study, the project had a total of 78 workers (50 workers from the two different subcontractors and 28 workers hired directly from Project B).

Additionally, a system's training session was provided for the project manager team and for the workers during a daily meeting with the 78 workers present; this was part of the game dissemination strategy. In addition, a campaign was undertaken to publicize the game through flyers and posters and a 21 inch TV was installed.

During the implementation, the project manager decided to involve only the workers directly hired by Project B in the game, in order to evaluate the implementation and its impact on a small scale and with a more controlled number of workers. Also, the project manager decided to start the implementation only with the individual rules (rules 1-6 – see Table I) in order to have a better perception of benefits and drawbacks of the gamification process and the system, despite the fact that the manager had understood the importance of the collective rules (rule 7 – order and cleanliness of the workplace, and rule 8 – completion of the work package in a timely manner and with

Rule	Point	Group coverage	Frequency	Responsible for assessment
(1) Removal and return of work tools	−3	Individual	Daily	Person in charge of controlling tool loans
Objective: to control the loan tools. Due to the fact that it is an activity that not all workers perform, it will not be given a score for its accomplishment, and because that would result in an advantage for these employees. To encourage the implementation of this task, a negative score for non-compliance will be assigned, using a framework of controls and control sheets. Assess the conservation status of the return				
(2) Use of individual safety equipment and compliance with safety regulations	3	Individual	Daily	Safety manager
Objective: to assess the use of individual protective equipment and compliance with safety standards for workers. In order to evaluate this rule, routine inspections of the workplace should be conducted to identify possible breaches of the rules, including the non-use or unreasonable use of individual protective equipment, the use of control and registration records. Score for those who have no comment				
(3) Attendance of daily safety meetings	2	Individual	Daily	Safety manager
Objective: to evaluate the mandatory attendance of workers in the daily meetings concerning safety measures. The attendance of this meeting is already recorded daily through a presence list, applied by the safety manager work. To facilitate the processing of the data using a control chart				
(4) Attendance	−20	Individual	Daily	Administrative assistant
Objective: to monitor the attendance of employees. The presence of the employee is considered a minimum requirement for any performance analysis; therefore, a score will not be given based on attendance. However, the penalty for unexcused absence should reflect the seriousness of this lack of commitment. Use timecards and attendance sheet				
(5) Punctuality	15	Individual	Weekly	Administrative assistant and foreman
Objective: to assess the degree of punctuality of employees. To encourage punctuality, a score of 15 points per worker will be credited, if the sum of the daily delays for an entire week does not exceed 75 minutes. Analyze timecards				
(6) Subordination and discipline	−5 to −20	Individual	Daily	Foreman and junior engineers
Objective: to evaluate possible problems involving issues related to subordination and discipline. For this rule, the responsible teams should conduct review when there are any signs of problems related to insubordination and discipline. This is a very delicate and subjective category; point deductions will depend on the degree of seriousness of the situation				
(7) Order and cleanliness of the workplace	20	Collective	Daily and weekly	Foreman and junior engineers
Objective: to assess the degree of organization and cleanliness of the workplace. Prizes for a desktop that only contains equipment and materials needed to service and is free of waste and debris "during" and after work. This evaluation should be done by junior engineers, with participation of those in charge. Credited to any team				
(8) Completion of the work package in/on time and with a high-quality standard	40	Collective	Weekly	Junior engineers
Objective: to improve the completion of the work package on time and with a high-quality standard. A score is established for the team components that meet their goals; the expectation is that the rewards, intrinsic or extrinsic, will generate a motivational factor. There is a weekly review at the time of the PCC (percentage of work packages completed) measurement				

Table I.
Rules and points system of the GamifiedSystem

high-quality standard). In addition, the worker supervision team (two junior engineers, the safety manager and the foreman) was reduced; so limited resources could be used during this implementation.

Two cycles of implementation were developed with four weeks for each cycle. During the first cycle, information about the accomplishment of the weekly work assignments, data related to the established rules and photographs were collected on a weekly basis by the main author of this paper. Also, the main author provided feedback on the results of the game for the workers once a week during the daily meetings, using the Gamified Construction Project System, since feedback loops are an essential part of games.

Based on the findings of the implementation of first cycle, adjustments of the game rules and the functions of the system were made and GamifiedSystem v.1 was created. During the second cycle, a simple quiz with five questions concerning the understating of the workers on the information provided by the system was given to 24 workers, which represented 85 percent of the workers who were part of the implementation. That data were collected during the four daily meeting sessions in this second cycle.

Additional structured questionnaires and focused interviews were administered after implementation in order to assess and validate the game design and gamification process: first, focused interviews with the project manager, the schedule manager, the two junior engineers, the foreman, the crew leader and the safety manager to evaluate the transparency improvement in terms of production tasks and workers' performance; second, structured questionnaire administered to the project manager, the schedule manager, the two junior engineers to evaluate to which degree the screens provide expressiveness and communicability for the users; third, structured questionnaire administered to 11 workers, ten of whom were workers hired by Project B who had answered the diagnosis survey at the beginning of the study, together with the winner of the game. This questionnaire aimed to collect the workers' perception about the transparency of the system, and their motivation to be involved in its implementation; fourth, structured questionnaire administered to the project manager, the foreman, the crew leader, the safety manager, the two junior engineers and the individual responsible for tool loan control, in order to evaluate the effectiveness of the gamification since those people were involved in the implementation of the gamification process.

The interviewees were asked about their perception concerning each attribute in each structured questionnaire, as shown in the Findings section. The criteria levels adopted were the Likert scale from 1 to 5, meaning 1– bad, 2 – poor, 3 – fair, 4 – good, and 5 – excellent; then an average was calculated based on the number of interviewees and the grades given.

Data analysis

Two main constructs were established for the critical analysis of the gamification process according to the following definitions. Each construct was decomposed into sub-criteria to simplify the data analysis and for internal validity and multiple sources of evidence were used to triangulate data; this means, validating the data through cross verification from two or more sources which reduce the researcher bias and allow to draw conclusions. The main sources of evidence included interviews and the structured questionnaire administered, field notes, electronic data from the Gamified Construction Project System and participant and direct observations (see Table II):

(1) Transparency of the weekly work plan and workers' performance refers to whether the gamification process communicates useful information to the

Construct	Sub-criteria	Source of evidence
Transparency of the weekly work plan and worker performance	Transparency improvements for project management and supervisor team Transparency improvements for workers Expressiveness and communicability of the screens for the project management team	Focused interviews with project manager and schedule manager, two junior engineers, foreman, crew leader, safety manager Structured questionnaire about expressiveness and communicability administered to the project manager and schedule manager, two junior engineers Structured questionnaires administered to the workers before and after the implementation Simple quiz given to the workers during implementation Participant and direct observations Field notes
Workers' engagement	Effectiveness of the gamification Willingness of the worker to complete the task Worker motivation	Structured questionnaire about effectiveness of the gamification administered to the project manager, two junior engineers, foreman, crew leader, safety manager and those responsible for tool loan control Structured questionnaires administered to the workers before and after the implementation Data collection from the GamefiedSystem Participant and direct observations Field notes

Table II.
Constructs, sub-criteria and sources of evidence

people involved. In this study, the transparency improvements concerning assignments and goals of the production planning and the workers' performance were measured, as well as the expressiveness and communicability screens of the GamifiedSystem. Expressiveness means that the visualization is capable of expressing all-important data for the user, without providing insufficient or extraneous data (Nascimento and Ferreira, 2005) while communicability means that the interface is capable of communicating the logical design, the intentions of the designer and the interactions among the intended actions and the real actions (mapping is the technical word) (Prates *et al.*, 2000; De Souza, 2005).

(2) Workers' engagement refers to what extent the workers were engaged and motivated to perform the tasks established as a result of the gamification process, and also as to whether the game mechanics and dynamics that have been defined for the system provide game thinking into the non-game application with the aim to motivate and engage the system user (Zichermann and Cunningham, 2011). In this study, the user was the construction worker, and the effectiveness was measured by the following mechanics and dynamics: badges, the ability to respond quickly, transparency and feedback, the ability to work with a target, the point system (competitiveness) and cooperation.

Findings

Gamified construction project system (GamifiedSystem)

The Gamified Construction Project System is a flexible web computing system, which is adjustable to the reality of an individual project's rules and policies. This system has two interfaces. The first is the online viewer, which is used to display information regarding the weekly work plan, the control of this work plan and the performance evaluation of the construction workers. The second interface is the administrator mode, where input data and data control can be performed. As already mentioned, Table I presents the first eight rules (only 1-6 rules were implemented) and the point system established in GamifiedSystem V.0, which adds score points for complying with the rules and subtracts score points for not complying with the rules.

A cycle of game implementation consists of a total of one month with four sub-cycles, as shown in Figure 3. The first week has a different dynamic from subsequent weeks because no data have been collected and the rules have not been updated. Therefore, the following explanation starts after the second week. The preparation is based on the weekly work planning of the LPS (Ballard, 2000). Initially, the weekly work plan is prepared by the project manager, junior engineers, foreman and crew leaders; the plan considers the quality criteria proposed for the assignment regarding the definition, sequence, soundness and size, according to Ballard (2000), and all work must be allocated to a team. Then, the assignments of the weekly work plan are uploaded into the GamifiedSystem (see Figure 4 – screen 1). Each work team has a different color, and the location of each package is displayed in a drawing on the screen. This work plan is distributed to all workers during the daily meeting and is coordinated by the foreman.

On the same day of the meeting, the data collected concerning the rules during the week must be processed, including the assessment of the accomplishment of assignments and workers' performance to update screen 1 and to generate data for screen 2, screen 3 (Figure 5), and screens 4 and 5. All screens of the game should be available for all workers during the week.

The junior engineers and the foreman are responsible for evaluating the completion of each assignment, identifying the reasons for non-accomplishment of them. Additionally, to identify each worker's compliance, all data collection worksheets should be properly filled out by those responsible for the assessment for each rule, as previously presented in Figure 3. After four weeks, a closing out meeting should be held to present the final result of the game to reward the top performers.

During the first cycle of implementation some technical and management adjustment were made in the system. Due to the amount of draws among the workers, a new rule (new rule 7) was created. This rule was evaluated only once during the game cycle by the foreman, the crew leader and the safety manager with the following question: "Is the worker willing to perform the tasks?" The evaluation involved providing a score from 0-10. From the calculation of the average of the three scores assigned to the worker, he may receive the following points: score less than 5: zero points; score 6: three points; score 7: six points; (d) score 8: nine points; score 9: 12 points; or score 10: 15 points. This rule resulted in a tie and began to portray the reality of the workers' performance. Even with the subjectivity of the evaluation of this new rule, this showed to be important. The supervision team works on a daily basis side by side with the workers, and is able to use its own judgment and general behavior criteria to analyze their performance.

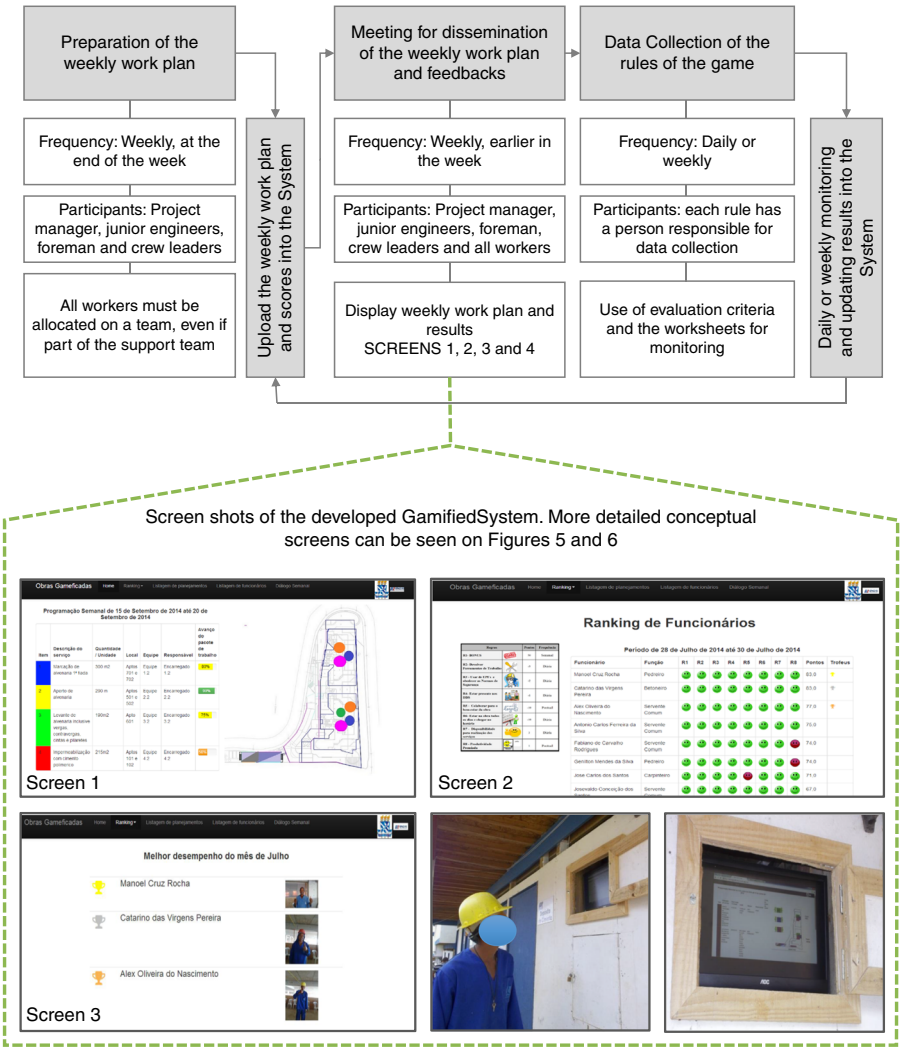

Figure 3.
Overview of the gamification

For the second cycle of implementation, a New Rule 8 – Awarded Productivity Seal – aims at evaluating the employees' motivation from the perspective of the project manager, the junior engineers, the administrative staff or the even the headquarter leaders were established. Additionally, a fixed cash prize (R$100.00), corresponding to approximately 8 percent of a mason's salary and 12.5 percent of a laborer's salary, was offered by the project manager to the top three "players" according to the game's ranking.

Impacts of the gamification process and the GamifiedSystem tool

From the constructs and sub-criteria defined and the data collected, the process of Gamification and GamifiedSystem tool was analyzed and discussed in terms of their impacts on the construction project studied.

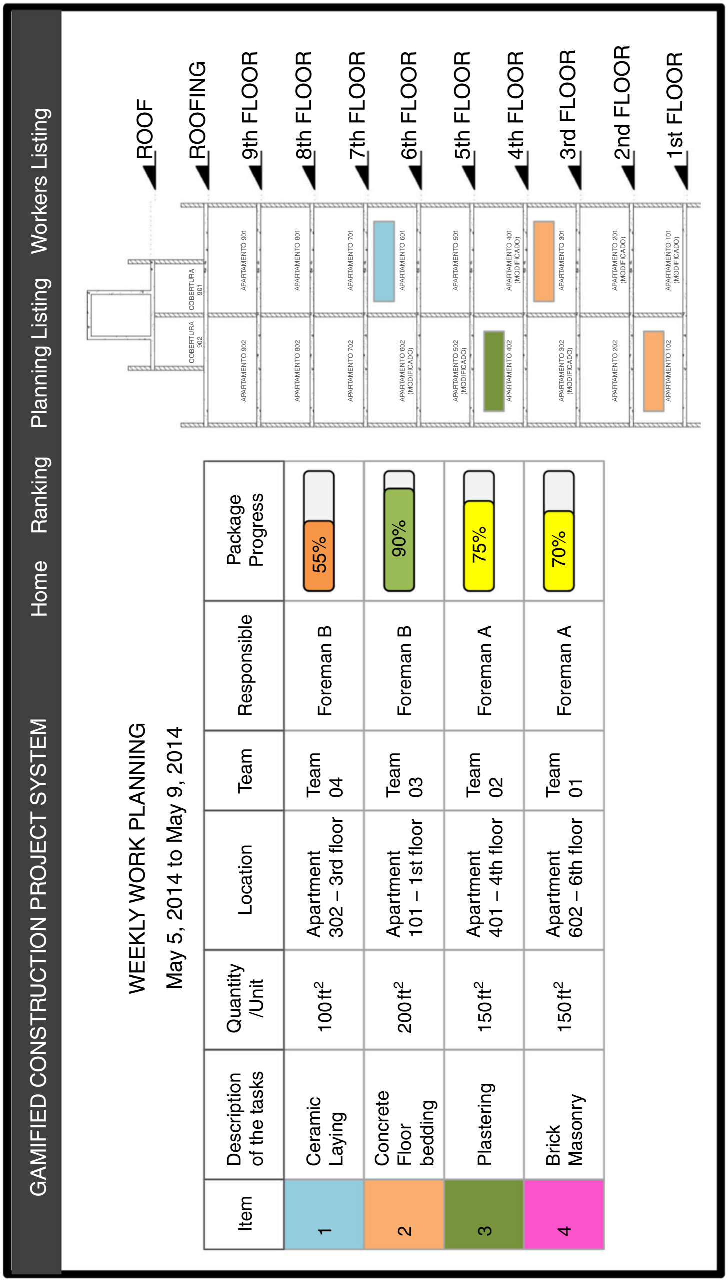

Figure 4.
Screen 1: weekly work planning

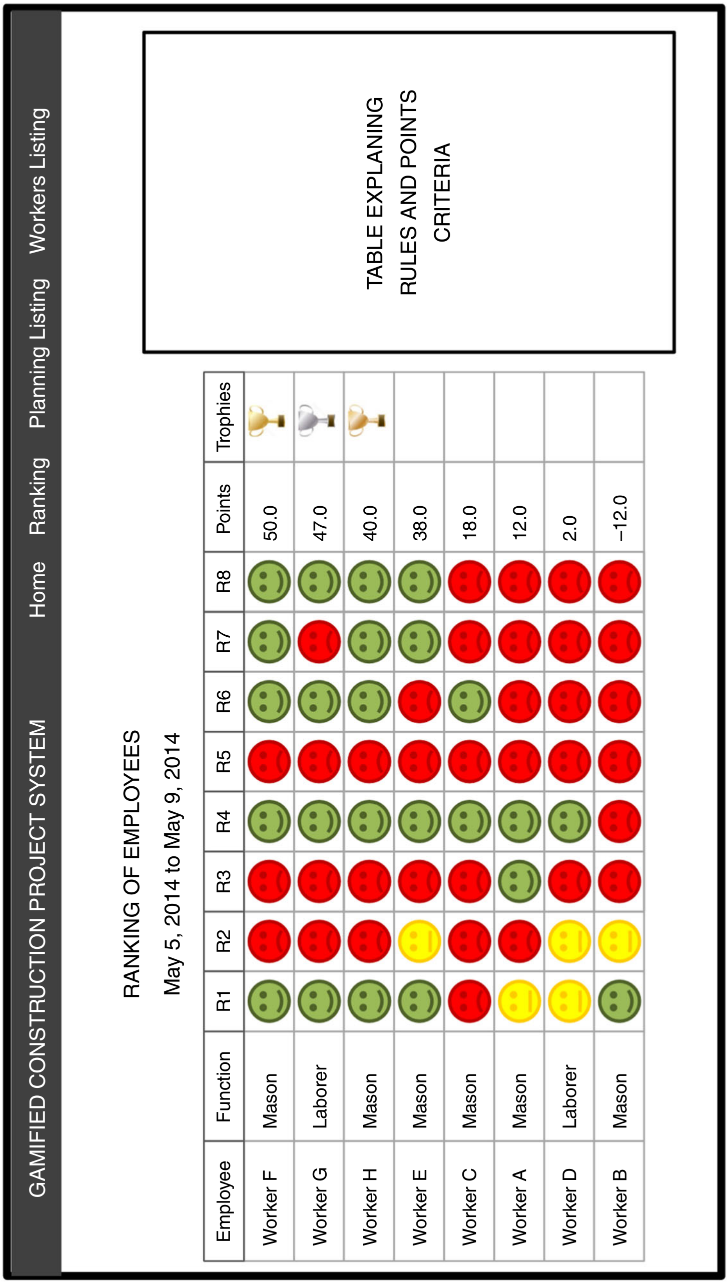

Figure 5.
Screen 3: weekly ranking of employees

Transparency of the weekly plan and the workers' performance. The weekly work plan, the ranking of the teams and the ranking of the employees' screens of the GamefiedSystem (Figure 6) were evaluated on a scale of 1-5, where 5 was considered excellent, in terms of expressiveness and communicability as measurement for transparency, by the project manager, the schedule manager and the two junior engineers.

The weekly work planning screen, the ranking of the teams' screen and the ranking of the employees' screen were evaluated by the management of the work with an average above 4.5 for the items content relevancy, simplicity, information architecture and focus on the worker. This shows that the expression of these screens is satisfactory. Only the mapping item score reached around 4.0 for the three screens. This shows that the images and information on the screens can still be improved for a more effective communication and the textual information provided by junior engineers could be written better. In ranking officials from the screen shown to the rules table had a low visibility of information to the user. The table space on the screen was too small to write the rule name, so the R1 codes were used, R2, R8, ... and they were not very clear to them. To improve this problem, a user suggested the adoption of icons that intuitively reflects the significance of each rule rather than codes.

From the viewpoint of improvement in information transparency for the project management and supervisor team, interviews with the schedule manager found that before the system implementation, the headquarters only had information about the accomplishment of tasks at the end of the month, and this information was provided by the project manager. After the system implementation, the headquarters had information about accomplishments and workers' individual performances on a weekly basis by accessing the GamifiedSystem. For the project manager, the use of the LCD monitor to disseminate information was helpful. He identified the need for improving the rules' dissemination to the workers and recognized a need for increased involvement during the implementation and operation of the system. For the two junior engineers and the safety manager, the system increased the information transparency for the employees and allowed them to identify their activities using the screens. However, the foreman and the crew leader did not have the same perception, arguing that the workers are not able to understand the information provided by screens.

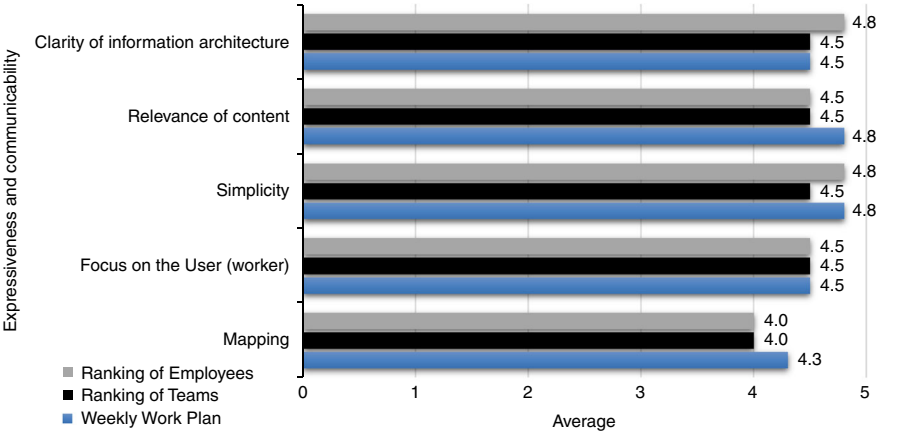

Figure 6.
Project management team's perception of expressiveness and communicability of the screens

The workers' perception of improvement in information transparency was analyzed, based on interviews before and after system implementation with the same group of workers, and the winner of the game was added in the second round of interviews. Before system implementation, only 10 percent of the ten workers interviewed, hired by Project B claimed to be aware of the weekly work planning; after the implementation, 82 percent of those workers said they knew what the weekly work plan was. Another question asked before the implementation was whether the workers had a clear idea about the tasks to be performed during the week and 30 percent of workers hired by Project B answered that they had a clear idea. After the implementation those workers were asked if they could recognize the location of their task by using the images, the color of their work package, the number of work packages allocated to the team through the system, and, respectively, 91, 82 and 82 percent of those workers said they could recognize them.

In addition, the results of the simple quiz administered to 24 of the 28 workers involved in the implementation showed an improvement in information transparency (see Figure 7): 100 percent of workers tested correctly identified the winner of the week; 87 percent of workers tested recognized the meaning of the icons (green, yellow and red symbol faces); 83 percent of workers tested could identify the location of the task using the images; 75 percent of workers tested knew how many points they had earned in the week; and 71 percent of workers tested correctly recognized the color of their team. These results show that during the implementation, the workers were aware of the game, and the meaning of the symbols; however, more specific information about the assignments and individual score points could be improved.

Therefore, based on data collected from interviews, structured questionnaires, quiz and direct and participant observations it was possible to affirm that transparency improvements related to the weekly work plan information and workers' performances were observed by all involved. The information was disseminated either through displaying the information on the construction site or remotely via the web. Even with the lack of perception of improvements from the viewpoint of the foreman and the crew leader, the results showed that the workers had a good understanding of the screens, even though the textual information had not archived satisfactory communication. The lack of perception of the transparency improvements could be attributed to cultural barriers to the introduction of new practices and technology on construction sites, reinforcing that those issues need to be better addressed in new studies in order to have better engagement from the field leaders, and consequently, to have better results during the implementation.

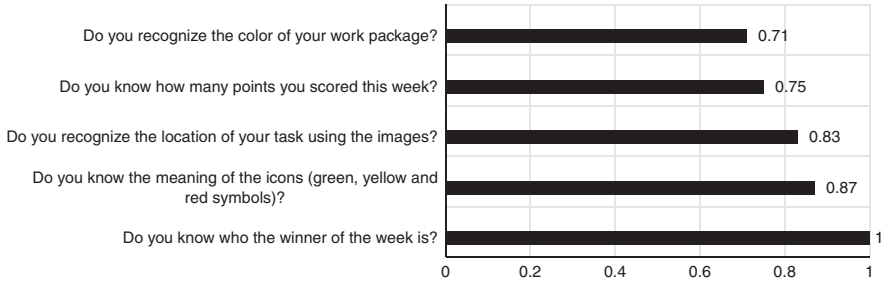

Figure 7.
Results of the quiz administered to workers during the implementation

Employee engagement in the implementation process. Figure 8 shows the effectiveness of the gamification mechanics and dynamics from the perspective of the management and supervision team. The "badges," which correspond to the Awarded Productivity Seal, were the most effective metric with an average of 4.7, while the "collaboration" metric had an average of 2.7; the collaboration score was unsatisfactory because the collective rules (rules 7 and 8 from the first proposal) were not applied. All of the other mechanics or dynamics obtained an average of above 4.0, which indicates that they were effective.

During the implementation, the Awarded Productivity Seal had an important impact on improving worker performance. Of the 11 workers interviewed, 91 percent mentioned that the Productivity Seal was a good or excellent mechanism. Of the 200 badges planned, only 24 were awarded to the workers, mainly by the junior engineers indicating a need for more involvement of the other members of management. It was concluded that this mechanism could be further exploited in other opportunities.

Additionally, during the interviews after implementation, the workers mentioned that they understood and liked the game; they felt motivated to improve their performance to win and they were motivated to earn the Productivity Seal and the Cash Prize. This means that the workers were extrinsically driven by possible rewards, such as earning additional money or winning an award seal (Zichermann and Cunningham, 2011).

The workers received feedback about their performance on a weekly or monthly basis after system implementation. This contributed to the modification of some workers' undesirable behavior in order to achieve better scores in the subsequent rounds of the game. This was an important impact for the workers because, at the beginning, 70 percent of workers hired directly by Project B stated that they had never received feedback.

From the new Rule 7, it was possible to evaluate the workers' willingness to meet requests throughout the implementation process, as shown in Table III. The results show a significant increase in the worker's willingness from the first cycle to the second cycle, indicating that the system had a positive impact on employee engagement in complying with the rules.

Regarding motivation, the initial diagnosis found that 70 percent of workers hired directly by Project B felt motivated to perform their tasks; however, interviews after

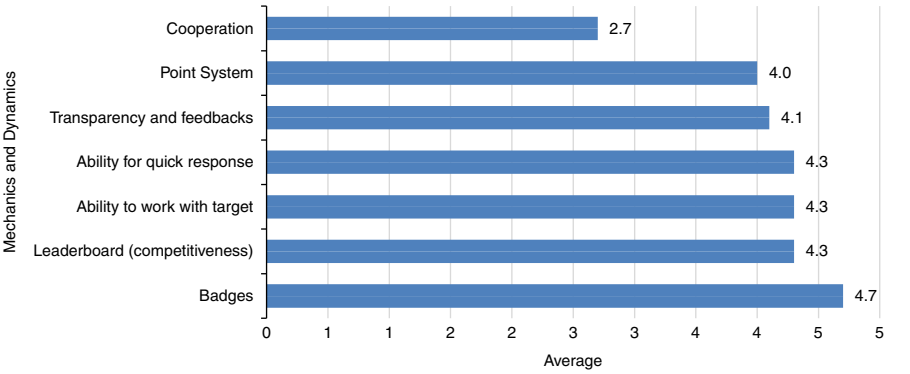

Figure 8.
Project management team's perception of the gamification mechanics and dynamics

implementation showed that 100 percent of workers mentioned that they felt motivated to win the prize, 55 percent sought to change their behavior to score more, and 82 percent of workers had more desire to increase their score. Therefore, an increase in the worker's willingness and an improved motivation to perform their tasks was observed due to the implementation of gamification process.

Lessons learned from the gamification process implementation. Table IV summarizes the good practices and the improvement opportunities identified during the gamification process implementation and in the GamifiedSystem tool.

Throughout the two cycles of implementation, changes were made such as additional rules, an adjustment of the point system, improvements in the game's

Workers' willingness	First implementation cycle	Second implementation cycle
Good	6	11
Fair	8	10
Poor	14	4
Workers sample	28	25

Table III.
Workers' willingness throughout the implementation

Construct	Best practice	Improvement opportunity
Transparency of the weekly plan and the workers' performance	The game's screens were considered simple and focused on the user, with clear information architecture and with relevant content by the managerial team	The textual communication related to the weekly plan and the rules for workers needs to be improved
		Improvements are needed related to the screens' images
	Dissemination of information related to the weekly plan and project rules and policies	Low perception of benefits of information transparency by foreman and the crew leader
	Monitoring of information about the accomplishment of work packages and individual worker performances	Major deficiencies in the weekly work planning made it difficult to identify data collection and dissemination indicators
	Evidence of improvements in transparency of information to different people involved	The project team needs better education concerning the Last Planner System
Workers' engagement	Evidence of better worker engagement for improving their productivity and performance due to the game	Improved managerial team engagement is needed for distributing the productivity awards and showing the importance of the program for the project to the workers
	Evidence of increasing worker willingness to perform the task due to game	Cooperation was the least effective mechanic because the collective rules were not applied during implementation
	The productivity seal and the cash prize were tangible benefits recognized by the workers, contributing to better performance	The project team faced difficulties in incorporating the gamification process into the production routine due to a small team size and general managerial deficiencies
	Feedback was also effective through the gamification, resulting in a change in some of the workers' behavior	

Table IV.
Best practices and improvement opportunities in the gamification process and the GamifiedSystem tool

screens, the standardization of meetings to disseminate the game's results and feedback for workers, and the introduction of extrinsic motivation mechanisms such as cash prizes (monetary) and productivity seals (non-monetary). Despite the recommendation of a balance between extrinsic and intrinsic motivation in gamification (Zichermann and Cunningham, 2011), it is important to highlight the need to introduce a more intrinsic motivation gamified strategy for meaningful engagement in the process, since there are studies showing that extrinsic motivation can produce a variety of negative effects, including decreased intrinsic motivation (Deci *et al.*, 2001).

Therefore, the learning process of the workers as users and the managerial and supervisor team as facilitators was observed throughout the implementation, despite the identification of several opportunities for improvements, as described below.

Some of the difficulties in the implementation of the gamification process were directly related to management deficiencies in construction projects. Despite all the efforts undertaken by Company 1, this one still has a traditional operations mode in terms of production, management and employment relationships, which influences the development of the study; for example, the project manager felt that they had to spend too much time on planning issues, corroborating with the findings presented by Viana *et al.* (2010). Major deficiencies in LPS and its implementation, such as the poor standardization of the weekly work plan, infrequent weekly planning meetings and poor data collection of indicators for feedback, made the full implementation of the gamification process in the studied project difficult. Another problem was the small size of the management team. In the studied project, a low managerial effort was made for data collection related to the worker performance and work package information, which delayed the feedback process.

Other barriers identified were related to individual qualifications of the construction workers, which is consistent with results from Viana *et al.* (2010). The foreman and the crew leader had difficulties in perceiving the benefits of information transparency through the screens, most likely because they believed that informal communication is sufficient. The introduction of new concepts and practices in the field often faces resistance from the crew workers involved; considering both cultural and educational issues observed in the Brazilian Construction Industry, which need to be better addressed. Additionally, due to the craft and the physical nature of construction work, the workers need more time and need to go through more implementation cycles to be more familiar with the game because it involves being aware of the information technology.

Finally, because the system is focused on field workers and daily activities and routines, to provide effective communication on site, the images and textual information of the game need to be simpler and more accurate concerning the rules.

Despite the rules about the accomplishment of work assignments on time and about high-quality standards and the fact that the assessment of the organization and cleanliness of the workplace were not implemented and tested, due to several reasons mentioned before, it was possible to identify the effectiveness of the game design and gamification process in terms of the improvements in information transparency and the individual worker performance.

Conclusions and further studies

This work contributes to the theoretical field of VM on construction sites by integrating VM and a gamification technique. The adoption of gamification in construction showed itself to be an interesting strategy which contributes to the VM field as well as installing vital information as close to the user as possible, and generating new levels of employee inventiveness and contributions, through encouraging the workers to adopt them, or influencing how they are used. It is envisioned that gamification may work in the construction field by making technology more engaging to the workers, by encouraging workers to engage in desired behaviors, by helping to solve practical problems such as information transparency, and also encouraging workers to perform chores that they ordinarily consider boring, such as the return of the tools. Therefore, the gamification can generate a membership and, at the same time, can make the rules and procedures of the construction project clearer, more visible and more accessible.

Another theoretical contribution was the definition of constructs and criteria for the assessment of game design and gamification process, such as transparency of the weekly plan and workers' performance and workers' engagement.

In practical terms, this study brings the planning and performance information to those close to the matter, operating, exposing and making clear which activities, quantities, tasks, teams and feedback are needed for the construction worker. The GamifiedSystem developed for planning, control and individual evaluation used some game mechanics, such as the point system, leaderboards, badges, feedback, and VM, and generates a behavior-oriented approach, and was directed to achieving targets, including the understanding of the work plan and greater participation at the operational level.

Important impacts were observed throughout the gamification process and the developed GamifiedSystem tool, such as the following:

- increased transparency in terms of better visualization and monitoring of the weekly work goals, the assigned crews and the localization of the task for the workers, and the workers' performance;
- better worker engagement for performing each task, induced by the mechanics and dynamics previously mentioned, and better adherence to project rules and policies and changes in workers' behavior; and
- effective gamification, mainly through the mechanics and dynamics, such as badges (productivity seal), the leaderboard (ranking), the cash prize and quick feedback.

Due to the limitation of the implementation of the system in only one project, important assumptions of the game, such as the collective rules, which focused on the production control, were not tested. Further studies are necessary to evaluate whether the system developed here also encourages the workers to achieve the goals set in the weekly schedule, drives the team to complete tasks on time and with high-quality standards, and keeps the worker motivated. Further studies are also necessary to implement and test more intrinsic gamified strategies. In addition, new functionalities should be proposed in the game, such as the use of mobile devices, to make data input easier.

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