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A GAMIFICATION SYSTEM FOR IMPROVING CIVIL CONSTRUCTION PLANNING AND EXECUTION

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The gamification of activities is evolving and currently being used in enterprise contexts. This technique has proven to be an effective method to promote engagement and motivation of employees who deal with repetitive tasks in areas such as civil construction. This paper presents a gamification system to disseminate and support short-term planning and management in a civil construction site. The system aims at improving transparency and communication between the management and operational levels besides promoting employee engagement. In particular, we apply the principles of visual management and gamification techniques for the development of a web system that supports weekly planning and review of individual and team performance on construction sites. The system exhibits the workers' activities within the construction site as well as rankings of team and individual performance based on the fulfillment of predefined rules. These rules are used to evaluate users regarding punctuality, engagement and adherence to security recommendations. We deployed our system in a civil construction site with 100 workers and results show that the system opens up an important tool for improving transparency concerning about the tasks of weekly planning.

Keywords: Keyword1; keyword2; keyword3.

1. Introduction

Gamification is the use of game elements, such as mechanics, in non-game contexts for the purpose of engaging users to perform determined actions and making them have more fun in the process^{5,11,27}. The aim of this technique is to make boring or repetitive activities more pleasant. This is usually intended to create gameful

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experiences, motivate desired user behaviors, and generally, increase joy of use,^{5,11}. Recent research conducted by⁴, shows that gamification has become an important part of the business strategy of many companies, for the purpose of engaging employees and retaining customers.

The insertion of game mechanics into a corporative environment makes the learning process easier and more fun²¹. Games can naturally motivate by entertaining, engaging users with rewards and stimuli, and training by involvement and learning. The “gamified” professional develops characteristics like leadership, cooperation, competitiveness and the ability to work with goals and make quick decisions²⁷. Humans are naturally competitive and they are more capable of accomplishing tasks when they are fun or a social reward is involved²¹. For this reason companies have applied gamification activities to engage thier employees to carry out regular jobs with more fun.

The field of Civil Engineering is constantly expanding, and the technology related to this area of study is also growing. Investment in innovation at the construction site is now necessary to improve communication among the many factors on the production chain; it helps improving control over the labor supply, materials and other resources. Production planning and control is essential, as they have a large impact on productivity and ensure that deadlines will be respected⁹. Additionally, most services in civil construction do not use a production line to improve productivity, unlike other industries in which many repetitive tasks are automatized. Therefore, Gamification encourages work engagement and facilitates the management of the construction site.

Based on these concepts, we propose a Gamification system to visually assist, managers and workers, with their activities at the construction site. We intend to evaluate how this Gamification system encourages civil construction workers to achieve weekly goals established with short-term programming and how managers can benefit from workers who are more motivated and focused, as well as the difficulties in the implementation of the system and how the system impacts the productivity of workers.

This work is structured as follows: In Section 2, we describe the concepts that support this proposal including gamification, social computing and civil construction; in Section 3 we present related works; Section 4 depicts the gamification system and how the gamification rules are set, and in Section 6 we present an evaluation of the system at the construction site and discuss points of improvement; and finally, in Section 7, we conclude and present ideas for future work.

2. Background

For a complete understanding of this research, as well as the ambitions related to the areas involved, it is necessary to understand the main issues: gamification, social computing and civil construction, in addition to concepts related to well-being at work and the involvement of employees. The themes are presented in different parts,

and the most relevant aspects are discussed.

2.1. *Social Computing*

Social computing is a general term used in the field of Computer Science to address the receipt, processing and dissemination of information about social behavior through computer systems¹⁹. Social computing has become an important concept in business. In¹⁹, in the weak sense of the term, Social Computing is the support of any type of social behavior through computer systems. It is based on creating social contexts with software and technology. Blogs, email, instant messaging, social networking services, wikis, social bookmarking and other software with which people can interact socially represent the idea of social computing.

According to¹, Social Computing is already viewed as an important social phenomenon in terms of its scope, use of time and activities. In the context of this work, the principles of social computing are applied to engage workers at a construction site with a serious web based game. Thus, we hope to achieve positive results beyond the game itself, e.g., socialization and joy. We believe that this collective engagement will push workers to be more motivated and effective at work.

2.2. *Gamification*

Gamification has emerged as a new trend in Information Systems and is defined as the use of game design elements in non-gaming contexts⁷. According to²⁴, play is the preferred way of learning and challenging the human brain because the thought of play is the opposite of seriousness, and most people do not realize that most relationships are governed through board games, political games, law, financial games, love games, advertising, etc.

The spirit of play is fundamental to human life and society, inspiring the visual, musical, and verbal arts and other elements that are valued by the culture. Games have the ability to develop a state of balance, creativity and objectivity. In addition,¹⁶ suggests that the ultimate goal of gamification is to incentive a non-game system user to have so-called game-like behavior: focusing on the task at hand, multitasking under pressure, working overtime without a discontented attitude, not accepting failure, etc.

In²⁷, the “gamified” professional develops characteristics such as leadership, cooperation, competitiveness, the ability to work toward targets and to make quick decisions; human beings are competitive by nature and perform their duties better if they are approached in a playful and fun way or even if there is some social compensation involved, as a motivational aspect to overcome their own limitations.

2.3. *Civil Construction*

In recent years, the construction industry has shown significant interest in new process improvement principles and practices that use visual management, which

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was also integrated into the Production Planning and Control at construction sites. This need has led managers to seek out new approaches to improve the involvement of their employees in complying with the weekly plan.

Lean Construction was named by ¹³ as a new management philosophy for production; it originated from the Toyota Production System - STP and was adapted for construction. This system of production increased competitiveness by identifying and eliminating waste in job site services. Losses are not limited to defective products in the mass production system, but also include loss of resources, manpower and equipment in activities that do not add value to the final product. To reduce losses, ¹³ proposes the principle of transparency, which is defined as a visually oriented production control principle that makes production processes more observable for those involved in the project ²⁶. To promote transparency, this research adopts visual management, this technique uses visual aids to improve communication processes and promote continuous improvement ¹⁰.

The development of a computer system based on techniques of gamification and associated with the construction environment is directly linked to the Lean philosophy; thus, the software will provide better communication between those involved in the work. Ultimately, this will actually achieve a significant gain in productivity, thereby reducing losses due to process.

3. Related Work

Gamification has been widely used as a tool for customer engagement. In 2009, Volkswagen built a musical keyboard on the steps of a regular ladder, and thus when people climbed the ladder, notes would be sounded. As a result of this experimental promotional activity, 66% more people used the ladder than on a normal day. In 2010, Starbucks gave custom Foursquare badges to people who checked in at multiple locations and offered discounts to people who became mayors of an individual store. In 2012, Freshdesk, a SaaS-based customer support product, integrated gamification features, allowing agents to earn badges based on performance.

In ¹⁷, Gamification is applied to significantly increase the willingness of users to keep personal files, enhancing the experience with management such a management. Like our work, they attempt to encourage players to perform repetitive tasks through a game. In the same line, ⁸ present a set of elements to gamify collaborative search systems. Although though this work is not linked to the civil construction domain, the authors attempt to intensify seeker engagement by applying game mechanics as we do in our approach. In a related reserach, ²⁰ analyze the actual behavior of employees when using a gamified system, whereas ¹⁸ aims at analyzing the contribution of gamification for non-recreational tasks, the same goal of our system. Similarly, ³ analyze the participation and motivation of personnel performing various tasks and activities. Similarly to our work, ¹⁵ applies rules to his experience in fostering company-wide safety initiatives. ¹⁵ shares firsthand examples of how gamification works, including stories from companies with which his firm has

worked.¹⁴ focus on the fundamental activity of engineering design using CAD systems and assess how they can be improved with game mechanics to provide more attractive and intuitive environments. This study shows some similarity to ours, but it is only a proposal to use gamification; there is no experimental evidence.²² uses gamification to overcome identified challenges and motivate its employees.²³ present the development of a Serious Game tool to improve the cognitive engagement of low skilled laborers; it was developed for capability training industrialized construction projects in developing countries. The success of this intervention is expected to improve their respective capabilities, thus improving productivity on the construction site. Similar to this work, they propose a method to encourage workers in a civil construction area to improve their abilities and thus make them more effective at that task. On the other hand, the emphasis on education is too strong in the article, and we want visible results.

Regarding the mechanisms used, this study adopts badges, ranking points, feedback and goals in order to investigate the behavioral effects inserting game engines through empirical studies as well as other related research here:² use badges as a mechanism to encourage participation in website,⁶ use points, ranking and challenge to increase user motivation to complete tasks.¹² use goals and feedback to assess the performance of a group of employees and²⁵ use points and ranking to investigate the motivation and involvement of participants. For the results only² adopt the method statistical analysis. All others, as well as this research adopt as sources of evidence interviews, questionnaires and system basis of data analysis. All cases listed in this section were short-lived and presented as well as in this study, positive results in the adoption of gamification.

4. The Gamified Visual System

The gamified visual system is a web-based platform which displays the ongoing activities in the construction site as well as the ranking of best workers based on their weekly accomplishments. Each activity is modeled as a rule, e.g. *Rule 1: Removal and devolution of the working tools*, and the ones who give back the tools along the week will appear in the top ranking of the gamified visual system. Actually, the gamified visual system is an adaptation of the short-term planning i.e., a weekly planning that includes a program for evaluating and rewarding workers based on rules that assess issues such as terminality, security and organization (see 5.1.1).

The system has two interfaces: i) *online*, on which viewers expose information on the construction site and ii) *administration* for monitoring and data entry by production managers, system administrators and third party personnel. The online interface consists of 4 sessions: i) *Home* which exhibits the ongoing planning, ii) *Ranking* (Team, Workers, Support, Trophies), which makes it possible to check the scores, iii) *Listing Planning* which displays all planning, and iv) *List of workers* which lists all employees working at the construction site.

4.1. The Game on the Visual System

The idealized game is conceived as a complete cycle of one month, with four other weekly sub cycles, as shown in Figure 1. During the month, six steps take place:

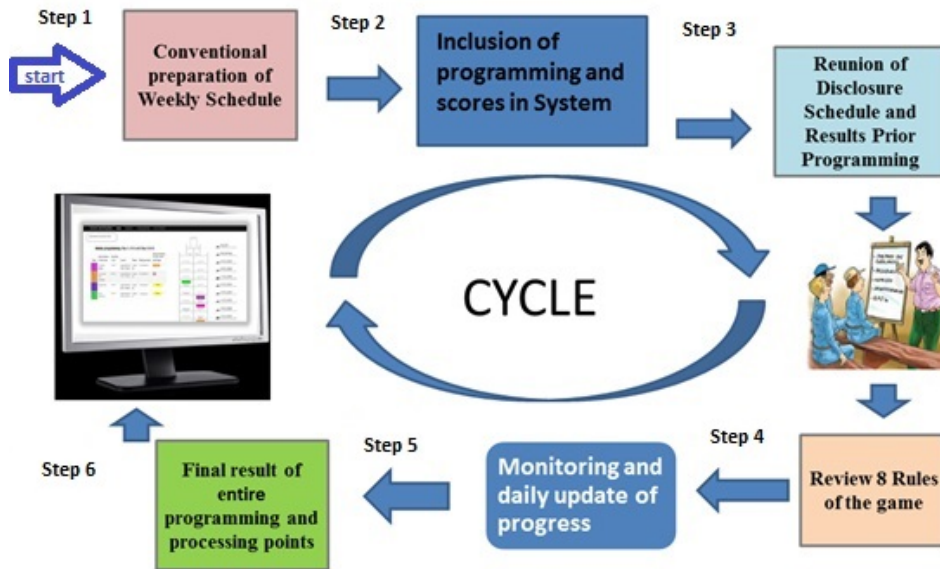


Fig. 1. Weekly cycle.

- (1) Preparation of short-term planning as performed normally. This information is usually provided by the production engineer.
- (2) Release of information to the weekly schedule in the system.
- (3) Weekly meeting with workers to introduce the new weekly schedule and discuss the results of the previous week.
- (4) Collect data on the construction site for the 8 rules of the game throughout the week.
- (5) Monitor and update the percentage of completion of services throughout the week.
- (6) Launch and process points this week. After the 4th week of play, the system displays the final score of the game.

Workers can visualize their progress in the system for each rule within a short-term planning (Figure 2). For instance, if a daily rule is strictly followed on 4 days of a week, a green face icon is displayed on the screen; if the rule is followed on 2 or 3 days, a yellow face is shown and finally, if the rule is followed on only 1 day, a red face is shown. If the rule has negative values, the colors are the opposite.

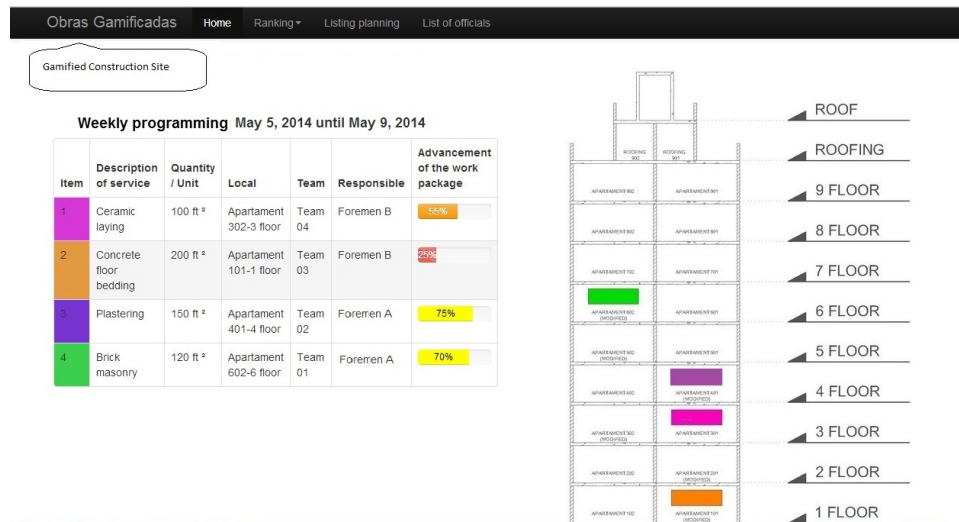


Fig. 2. Short-term planning.

4.2. Planning, Monitoring and Assessment of Gamification

The weekly planning should be adjusted and dimensioned with feasible service, well-defined teams and local execution, and all impediments to their achievement must be resolved. Schedules must be designed for a one week horizon, through meetings (usually at the end of the week) with the participation of the trainees and the project manager. On the same day of the meeting, the data collected during the week are processed, both the physical advance achieved and the rules fulfilled by each worker, to refresh the system. To evaluate the actual physical progress, field monitoring is necessary. This is the responsibility of the trainees and the production managers, who can evaluate if the tasks are being preformed by the workers. These data are important because they can measure what types of activities are not being accomplished and the cause.

Monitoring should be performed during the week, including the assessment of the established rules, as well as a daily filing and estimated advances obtained. Screens should be displayed daily, reserving approximately 5 minutes for the DDS (meetings with the project manager, workers and the safety technician to discuss project information and security issues) to dialog on the state of services. After performing these procedures in the 4 sub cycles, the monthly cycle is finished, and a closed meeting should be conducted to present the final results of the game in that period, in other words, recognize employees with superlative and award them.

Technical Outline: As previously said, the gamified web system is developed

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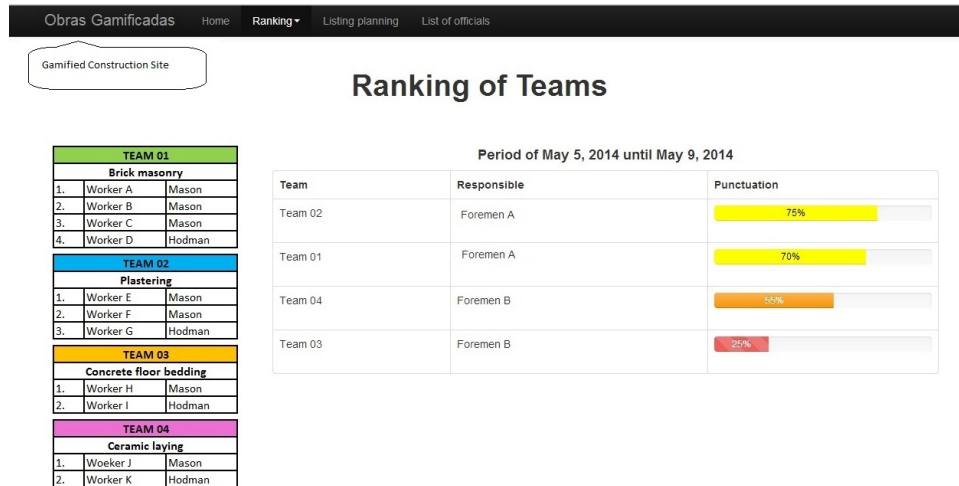


Fig. 3. Ranking of Teams.

Employee	Function	R1	R2	R3	R4	R5	R6	R7	R8	Points	Trophies
Worker F	Mason									50.0	
Worker G	Hodman									47.0	
Worker H	Mason									40.0	
Worker E	Mason									38.0	
Worker C	Mason									18.0	
Worker A	Mason									12.0	
Worker D	Hodman									1.0	
Worker B	Mason							N / A		-12.0	

Fig. 4. Ranking of Employees.

based on gamification techniques to disseminate and support short-term planning and management in a civil construction site. The system is coded in the Python programming language, and the web infrastructure is provided by the Django framework following the MVC architecture.

5. The Gamification Deployment Process on Construction Sites

Before any evaluation on the effectiveness of the gamified visual system, an approximation phase must be installed. It is almost impossible to draw the attention of workers and set up the whole game without introducing them to experiences they are not accustomed to. For this reason, an adoption process was implemented so that workers and collaborators could understand our intentions as well as how to collaborate and use the system properly.

The adoption process is essential to overcome numerous barriers that are not easily overcome unless physically at the construction site. For instance, not everybody can read or even see what is shown on the screen. Some workers simply refuse to take part in any other activity that supposedly brings them extra work time. To build an effective adoption process we had to understand and diagnose the working sites. It unveils the actual transparency of the weekly planning for the workers as well as expose several communication problems. As a result, it is possible to measure and derive the overall worker satisfaction with the company.

To do that, we employed an empirical investigation through two case studies called *Construction Site 1 Diagnosis* (developed by the junior engineer of the construction site 1, in October 2013) and *Construction Site 2 Diagnosis* (developed by the first author of this article in May 2014). While the first cycle was undertaken in May and June/2014, using the initial version of the gamified visual system, the second took place in July/2014 and used the final version of the system. Both are presented in the following and served as our learning units to set the rules to be implemented in the gamification system.

5.1. *Construction Site 1 Diagnosis*

The first diagnosis was developed by the junior engineer on construction site 1 during the month of October 2013, with the aim of lifting system requirements and creating rules for the game. To measure the weekly planning transparency and worker satisfaction, a survey with eight questions (A-H) was conducted with 24 workers (around 50% of the workers at the construction site).

Figure 5 depicts the eight questions (A-H) posed to workers as well as results achieved. In response to the question “Do you know the Weekly Programming of Services or the goals of the week?”, 42% of the workers answered “NO”, and 58% answered “YES”; the survey had a large number of negative answers, even with training and constant distribution of the weekly goals. However, according to Question A, approximately 62.5% of the workers indicated that they had a clear idea of their duty for the week. Frequently, they had an informal idea of the weekly tasks but were not familiar with the term Weekly Planning. Reasons for the lack of clarity regarding the tasks are uncertainty about obtaining tools and materials and the possibility of changes to the tasks during the week. These reasons were noted in the surveys by a large number of workers. Therefore, it is clear that there should be improvement in the information provided to the workers. On the other

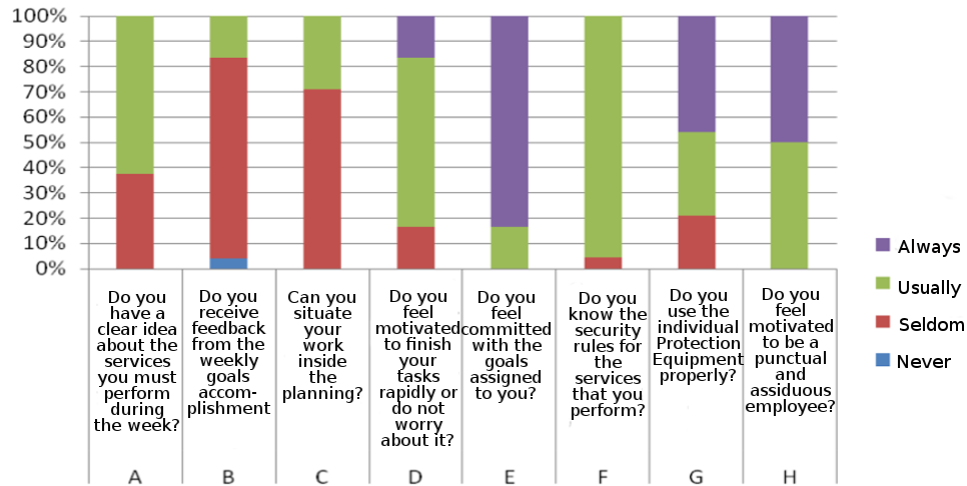
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Fig. 5. Workers Survey.

hand, 71% of the workers can seldom locate their work in the weekly planning, as seen in Question C. This shows that most of them do not know whether their tasks interfere with the progress of the overall construction. The Question B shows that 83% of the workers never or rarely receive feedback on their work, which can contribute to the lack of motivation and engagement of the workers. Questions F, G and H are related to the degree of commitment and knowledge about the rules of the workspace. The results are good and show that most of the workers know the rules, follow them and are committed to the work.

Table 1. Assessment of weekly planning transparency.

Good	Fair	Awfull	Bad
15%	50%	30%	5%

After the survey, an interview with the workers showed that the weekly planning is not transparent enough, as seen on the Table 5.1. Only 15% consider it a good way to show the tasks that must be performed during the week. In the interviews, most of the workers believe that this could be improved. With the results of the construction site 1 diagnosis, the rules for the gamified system were created. They are explained in the following section.

5.1.1. *Gamification Rules: An Outcome of Construction Site 1 diagnosis*

The outcome of diagnosis at the first construction site were a number of rules that will be deployed to the system as a set of evaluation criteria to assess the commitment of workers.

- **Rule 1: Removal and devolution of the working tools**

This rule has the goal of controlling when the worker receives and gives back the tools for the construction site. This rule gives the worker more responsibility for the tools that he uses. Not all workers use tools, so it would be unfair to give points for this rule. However, to encourage the workers, there is a negative consequence for those who violate this rule. The evaluation of this rule must be daily and on an individual basis, and it is the responsibility of the toolmaker and warehouseman. For each day that the worker asks for a tool and does not give it back, 3 points will be removed from his total score.

- **Rule 2: Use of security equipment and respecting security rules**

The objective of this rule is to motivate the workers to use Individual Protection Equipment (IPE) and adhere to the security rules. IPE usage and respect for the security rules is mandatory on the construction site. However, with the gamified system, it is easier to control this behavior. The worker who accomplishes all of the security rules is rewarded with 4 points. These points can be given by the security technician, but engineers, trainees and foreman can assign any fault to him.

- **Rule 3: Daily Security Dialog (DSD) presence**

Presence at the DSD is mandatory for all workers, including those who are outsourced. In this meeting, subjects like security, health, hygiene, society and the environment are discussed. Additionally, voluntary participation by the workers is requested to discuss these themes, but sometimes there is no participation. To motivate participation in the DSD, each worker receives 2 points for each meeting if the requirements are met.

- **Rule 4: Attendance**

The presence of the worker is a minimal condition for any performance analysis; therefore, there will be no reward for these criteria. However, if the worker misses a day of work without a reasonable excuse, he will lose 20 points.

- **Rule 5: Punctuality**

Each employee receives 20 points if the sum of delays for the week does not exceed 100 minutes. The analysis will be performed using the construction frequency control.

- **Rule 6: Subordination and Discipline**

The employee in charge of each team has to analyze the workers and flag any occurrence of subordination or discipline problems. This rule is very subjective and delicate, and it is hard to establish a punctuation loss because it depends on the occurrence severity. To overcome this problem the worker with this type of problem loses 20 points and the problem is analyzed by the engineer.

- **Rule 7: Organization and Cleanness**

The goal of this rule is to evaluate the degree of organization and cleanliness of the workspace. It is important to have a work environment free of rubbish and waste to maintain the work flow. Therefore, the team that accomplishes these goals receives 20 points; the responsibility for overseeing this aspect is rests with trainees and foremen.

- **Rule 8: Compliance with the Schedule**

This rule aims to improve deadline fulfillment. The punctuation and reward to the worker is a way to motivate him to consistently meet expectation. This rule also solves the terminality problem, whereby several small tasks remain to be done in a workspace, and the team or one of its members has to return and finish the job. These aspects are evaluated by engineers and trainees, and 40 points are given to each member of the team that respects this rule.

5.2. *Construction Site 2 Diagnosis*

The diagnosis on the second construction site 2 was longer because it simulated a real world evaluation of the gamified system twice. This time the game was finally designed based on more empirical and concrete evidences, which helped us to refine the rules that were previously set.

Thirty workers were chosen randomly, 10 employees of the construction company itself, 10 from the company responsible for the construction molds and 10 from the company responsible for the frame. Similar to what was done in Construction Site 1, the same survey was undertaken to measure the weekly planning transparency and worker satisfaction. As a result, 70% of the workers signalized not know how to situate their tasks within the flow of construction services; 60% of them never receive feedback on the accomplished goals. This shows that communication on the construction site needs improvement and that the informal way that tasks are passed on to the workers reduces transparency. Based on those evidences, we then kicked off the first cycle diagnosis.

5.2.1. *First Study Cycle on Construction Site 2*

To begin the study of Construction site 2, some activities had to be performed:

- (1) **Infrastructure Preparation:** to start the study on Construction Site 2 and begin the game with the workers, some equipment was necessary including a monitor to show the data, a projector for presentations and Internet access.
- (2) **Dissemination of the Gamification Process:** a week before the implementation of the system, the workers were advised about it. Folders were placed at the construction site introducing the rules of the game. Some meetings were conducted to give details about the process and the rules.
- (3) **Establish the Responsibility for Feeding the System:** the responsibilities for feeding each part of the system had to be established before the beginning

of the study; they were divided according to Table3.

Table 2. Responsibility for Feeding the System.

Rule Description	Responsible Role
Rule 1: Devolution of Working Tools	Warehouseman
Rule 2: IPE Usage and Respect Security Rules	Security Technician
Rule 3: DSD Presence	Security Technician
Rule 4: Attendance	Administrative Assistant
Rule 5: Punctuality	Administrative Assistant
Rule 6: Subordination and Discipline	Mater Builder

Evaluation of the First Study Cycle on Construction Site 2. The introduction of the system at Construction Site 2 began on 05/19/2014 in a DSD with the presence of 28 workers from the company, 46 workers hired from other companies and employees (engineers, security technicians, the master builder and foreman). In this first cycle, the 28 workers from the company were the players in the game. The master builder, the warehouseman, the trainees, the security technician, the production engineer, the administrative manager and the administrative assistant were the evaluators. It was decided by the management that there would be no competition in this phase; only results would be shown because the services were too dependent on each other to have a competition among the teams. It was also indicated that Rule 7 (Organization and Cleanness) and Rule 8 (Compliance to the Schedule) would not be considered.

In the first three weeks, the engineer sent the planning to the researcher by email and then inserted it into the system. The screens were captured and presented to the workers in the dining hall for 10 minutes per each day. That was not an effective way to provide information, so a monitor was installed at the construction sit in a place of easy access the following week. On the fourth week, the data were collected by the researcher every Friday, and the results were shown every Monday on the DSD and on the monitor, which generated a great deal of curiosity on the part of the workers. It was observed that many of the results were draws, as shown in Fig. 6; most of the workers fulfilled the individual rules and the security rules are not evaluated as they should be; thus, the draw persists. Additionally, rules related to attendance and punctuality did not have the expected effects once the workers were not used to arriving late at the construction site. To solve the problem with the draws, a new rule was added on the fifth week, Rule 7, which refers to worker availability to perform new tasks. The number of draws decreased after the changes, and the data reflected the real situation of the worker at the construction site.

Good results were achieved with the rule of discipline, which was viewed as very important by the evaluators of the system because a lack of discipline destabilizes the work environment and has an impact on productivity. The rule with the best

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Employee	Function	R1	R2	R3	R4	R5	R6	R7	R8	Points	Trophies
Worker F	Mason							N/A	N/A	90,0	
Worker G	Hodman							N/A	N/A	90,0	
Worker H	Mason							N/A	N/A	90,0	
Worker E	Mason							N/A	N/A	90,0	
Worker C	Mason							N/A	N/A	90,0	
Worker A	Mason							N/A	N/A	90,0	
Worker D	Hodman							N/A	N/A	90,0	
Worker B	Mason							N/A	N/A	90,0	

Fig. 6. Workers Raking Draws.

result was the tool devolution rule, cases of tools not being returned decreased after the beginning of the game.

The reception of the system deployment was generally good. The workers felt motivated to improve their results when some bad punctuation was shown on the screen. Management also had a good impression because they saw the changes on the workers behavior. Some difficulties were faced in the first study cycle. They are listed below:

- The engineering team is reduced and has no time to feed the system regularly. To have reliable and updated data is a necessary priority for the system feeding. In addition, people who have the necessary information (the security technician, master builder and foremen) do not recognize the importance of data transparency.
- There is an interest in the gamification deployment at the construction site, although there are no resources to promote it.
- The rules are not being used with the desired criteria. It is necessary to improve the observation, especially in terms of the rules related to security.
- Workers who have no acquaintance with computers need time to become more comfortable with the information displayed in the system.

The greatest challenge faced at this phase was obtaining information. Even with the approval of the engineers and construction managers, it was hard to get the necessary data to feed into the system.

5.2.2. *Second Study Cycle at Construction Site 2*

To start the second study cycle, some changes had to be implemented to the rules of the game. These changes were derived from the first cycle results and meetings with the management sector. It was established that some rules from the previous tests would continue with some changes to their punctuation and a bonus would be adopted to avoid negative scores, which could discourage the workers. The changes are listed as follows:

- **Rule 1 - Bonus.** The goal is to motivate the worker to play the game. Each participant wins 50 bonus points in the first week.
- **Rule 2 - Removal and Devolution of the Working Tools.** This rule was not changed.
- **Rule 3 - Use of Security Equipment and Respect for Security Rules.** The number of points for this rule was changed. Now, the worker loses 2 points for each day that he does not use the IPE or disobeys any security rule.
- **Rule 4 - DSD Presence.** Each absence from the DSD results in a penalty of 1 point.
- **Rule 5 - Subordination and Discipline.** The points were changed for this rule; now the worker loses 10 points for each occurrence, and the engineer is responsible for judging each case.
- **Rule 6 - Attendance and Punctuality.** It is the combination of two rules; it was implemented because when the workers are late, they frequently do not go to the construction site, so the punctuality rule was having no effect on the final score. 10 points are discounted for each occurrence.
- **Rule 7 - Availability to Perform New Tasks.** The goal of this rule is to measure the workers' motivation to attend a new task solicitation. There is only one evaluation in each game cycle; the master builder, the security technician and the team foreman evaluate the workers based on the following question: Does the worker have the availability to perform new tasks? A grade from zero to ten is given to each worker and the score is calculated based on the average of the three grades. Those with an average of less than five do not earn points; an average of 6 earns 3 points; an average of 7 earns 6 points; an average of 8 earns 9 points; an average of 9 earns 12 points and an average of 10 earns 15 points.
- **Rule 8 - Awarded Productivity Emblem.** This rule evaluates the workers from the point of view of a visitor at the construction site. Every time someone from the office visits the site, he can offer an emblem to those workers that stand out in terms of productivity and motivation. At the end of the expedient, the worker gives the emblem to the warehouseman, who then adds the score. Each emblem is 1 point.

The new rules were presented to the workers and promoted with folders placed around the construction site. It was decided with management that a monetary

reward would be implemented as well; the three best workers are rewarded with money. The participants in the game were the same workers from the previous cycle.

Evaluation of the Second Study Cycle on Construction Site 2. In the first week, all the workers were given 50 points for participating in the first cycle; they also received points from the previous test, the average of the points each week is according to the criteria adopted in Rule 7. All the rules were used in this week, and only the weekly planning was displayed to the workers. In the second week there was no Bonus (Rule 1), and Rule 7 was not used. At the DSD, the results of the previous week were shown to the workers and they filled out a form to evaluate their understanding of the game. On the days of concrete placement, all the team has to be on the construction site until the job is finished; on these days, the engineering trainee gave the Productivity Emblem (Rule 8) to the workers who excelled at their tasks. The third week started once again with the DSD, which the scores and the planning for the current week were presented. The points concerning Rule 7, which measures the availability of the workers to do more tasks, were counted. Additionally, there were informal interviews with the workers to check their feelings about the gamified system, and it was observed that the Productivity Emblem was accepted by them. Most of them said that they liked to win the emblem, and those who did not win one were motivated to receive one. On the fourth week of the game, all the information, planning and results were presented on the screen monitor; there was no DSD this week. Only in the next week was a DSD conducted to show the final results, and the names of the winners and their rewards were revealed. A photo of the three best positioned ones were taken and placed on the construction site mural, as shown in Figure 7.

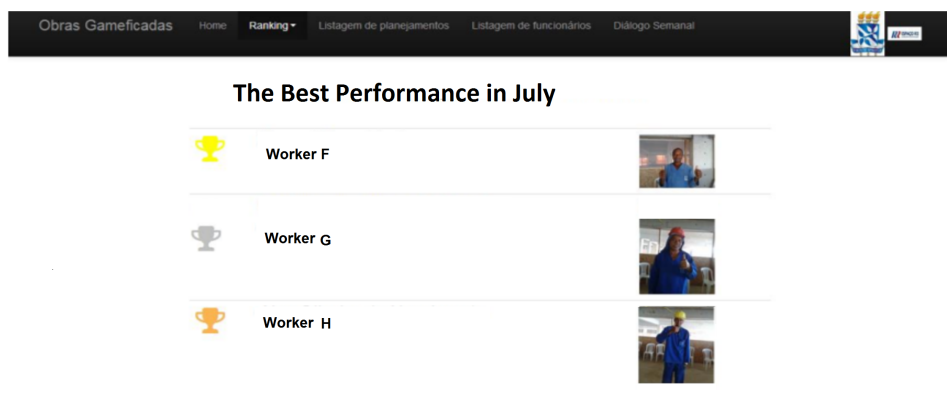


Fig. 7. Final Results.

The second cycle of tests at construction site 2 provided some important points

for this study. The main results are listed below:

- It is important to have someone inside the construction site who is responsible for collecting information from teams that are participating in the game. It can make the process more dynamic, and thus delays in the results are avoided.
- The workers were satisfied with the gamified system. They were motivated to fulfill their tasks and interested in winning the reward at the end of the game. Additionally, during the tests, workers from outsourced companies were curious about the system and asked if they would participate at some point, which shows that participating in the game would be interesting to them.
- The rules of the game can be changed and new ones can be created depending on where the system will be placed. To do this, it is necessary to study the situation at each construction site.
- As in the first cycle, the main barrier in the tests was the lack of information. The people responsible for collecting the data from the workplace often delayed these results, and this task had to be supplied by the researcher. Make the employees see the gamified system as a work tool is a challenge and it remove dynamics of the game.

All the results obtained in the diagnoses of both construction sites were extremely useful so that we could set up a real world evaluation using the gamified system based on very refined rules. Next section presents the evaluation of the gamified system.

6. Experimental Evaluation

The experiment aims to evaluate the effects of the gamification system at the construction site. We used interviews and surveys as a way to track results and gather information from workers about their experience with the system, to have transparency for the team and to keep workers informed of their tasks. The interviews were chosen randomly.

6.1. Evaluation Scenario

The evaluation scenario takes place at a civil construction enterprise that is interested in establishing a partnership and promoting the realization of the study. The selected enterprise is a mid-size business has been in the construction business in Salvador for 12 years. It is worth mentioning that few companies such as this accept the scientific challenge and allow researchers to take part in the construction process. Additionally, the fact that the enterprise had a previous approach to organization and planning for the tasks was important for its choice. The workplace is a residential building construction with two towers and 10 pavements with 2 apartments per floor in each tower. Additionally, there is 1 garage, 1 playground and 1 duplex penthouse. The high standard apartments are 282 m^2 to 373 m^2 and began being built in July 2013 with completion estimated for December 2015.

The building is on the superstructure phase of construction (pillars, beams and slabs), and there are 100 workers divided into three teams: one for assembling the model, one to assemble the bracket and one to deal with the concrete in the structures. If one team does not complete their task within the deadline, it affects the others. The model has to be built as fast as possible, and the frame needs to be installed correctly to make the concrete work viable. Therefore, it is possible to develop a game of collaboration involving all the employees with the objective being the accomplishment of the established goal.

To deploy the gamified system at the construction site, a monitor was installed at the construction entrance, a strategic location where the workers register their presence daily; thus, they have access to it every day and can see the status of each team. Twice a week, they attend meetings (DDS) to discuss ongoing problems and review the progress of work progress. At the first weekly meeting, which happens exclusively on Mondays, the production engineer presents the planning instructions as well as the results for the past week. At this moment, we show the workers their team and individual scores as well, which will be evaluated according to the new weekly planning. Every Friday, we feed the system with inputs collected from our own observations and information acquired from production managers.

6.2. *Evaluation Metrics*

To evaluate the effects of the gamified system on the construction site, we used interviews and surveys with all the people involved in the research. We had some aspects in mind to compare the results; they are:

- a) *Weekly planning transparency*: this measures how clear the information is regarding the tasks of the week among the people involved. We created three variables to translate this information into numbers (1) Transparency Degree for the Planning Sector (2) Transparency Degree for the managers (3) Transparency Degree regarding the process for the workers.
- b) *Gamification Effectiveness*: the goal of gamification is to use game elements to motivate people. Therefore, to measure this, we used the efficiency of the mechanisms used as a variable; this variable measures the following characteristics: (1) Fast Response; (2) Transparency; (3) Goals; (4) Rewards; (5) Competition; (6) Collaboration; (7) Points
- c) *Worker involvement/ Motivation*: to establish this, we considered three variables: (1) Degree of availability to perform the tasks; (2) Observable degree of motivation; (3) Worker motivation.

6.3. *Results*

In this section, we present the outcome of interviews, surveys and observations with the workers regarding the items mentioned in the previous section.

6.3.1. *Weekly Planning Transparency*

Table 3. Awareness about weekly schedule and weekly goals.

Not	Yes
17% (5)	83% (25)

One of the goals of this research is to improve the weekly planning transparency for all people involved in the production process. In previous surveys with workers, we realized that 83% of them are unaware of weekly planning as seen in Table 6.3.1. In fact all information about the tasks was given verbally by the production manager. So, there was not any alternative to consult information afterwards and there was no way to track the progress of the worker; feedback was only given at the end of the month.

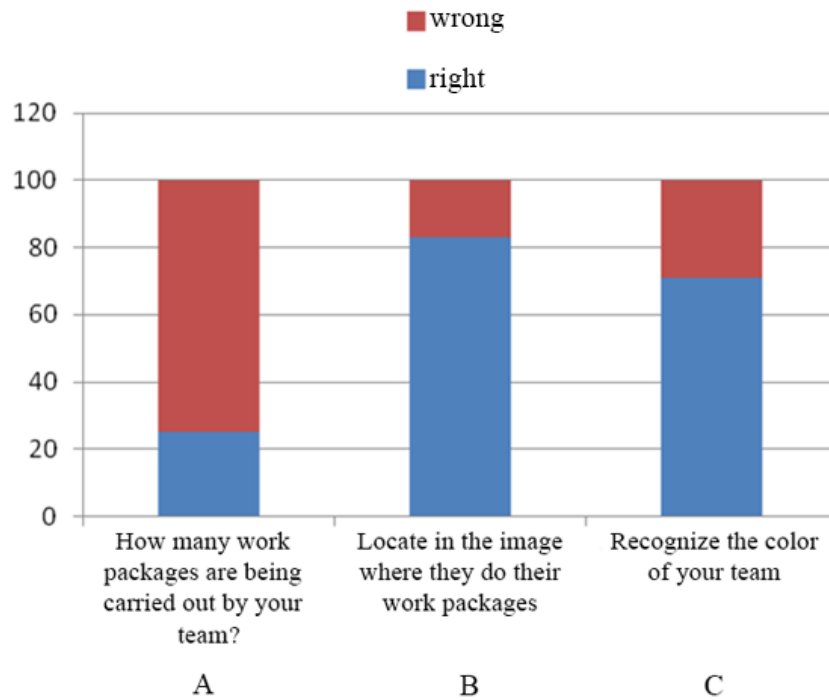


Fig. 8. Result of Evaluation about the Understood of the Game by Workers.

Figure 8 shows the results of a questionnaire addressing issues related to trans-

parency. Question A assesses whether the worker has a clear idea of the service that his team will perform during the week. As a result, only 25% of participants know how many work packages are being carried out by his team. This demonstrates that past textual information does not create good communication. As for Question B, 83% of workers could locate in the image where they do their work packages. The answers to Question C show that 71% of workers properly recognize the color of their team. We understand that workers have a good understanding of the visual of the screen. There was no change in relation to the work diagnosis phase; it was found that 70% of workers were unable to locate their service package within the weekly planning. Some more or less relevant factors contributed to this: *The experiment time was very short; the information is provided away from the workplace, although all have access to the system.* However, by direct observation, it can be said that the amount of information presented in the gamified system is sufficient to promote transparency in terms of what is happening at the construction site.

This problem could be solved with the implantation of the gamified system; we did notice an improvement in the planning and management process. Based on interviews and observation, the results for transparency were satisfactory once the managers responsible for the planning and the persons who monitor the workers had information on the current progress of each team and worker.

6.3.2. Gamification Effectiveness

To measure the effectiveness of the gamification process, we interviewed seven employees of the construction site who have the following functions: engineer, warehouseman, security technician, construction foreman, master builder and trainee. We asked them to rate some aspects of the gamified system; see Table 4.

Table 4. Gamification Mechanics Efficiency.

Game Mechanic	Bad	Poor	Fair	Good	Excellent	Average
Fast Response			1	3	3	4.3
Transparency			1	4	2	4.1
Goals				5	2	4.3
Rewards				2	5	4.7
Competition			1	3	3	4.3
Collaboration		4	1	2	0	2.7
Points			1	5	1	4.0

To achieve this result, we used an average for each concept: Bad = 1, Poor = 2, Fair = 3, Good = 4, Excellent = 5. To calculate the average of each game mechanic, we used these averages. For example, we calculated transparency in the

following way:

$$Average(transparency) = (1 \times 3 + 4 \times 4 + 2 \times 5)/7 = 4.1 \quad (1)$$

Almost all the mechanisms had a score near 4 except for Rewards and Collaboration which scored 4.7 and 2.7, respectively. Collaboration had a lower grade because the group rules were not implemented. The other results show that the gamification process had a good impact on the work environment.

6.3.3. Worker involvement/ Motivation

During the gamification process, two evaluations were performed to verify the degree of motivation the workers to attend to a request for a job. The data for the first evaluations were collected from June 16th to June 20th, and the data for the second one were collected from July 20th to July 25th, the last week of the experiment. The results are shown in Table 5:

Table 5. Worker Availability to Perform Tasks.

	First Evaluation	Second Evaluation
Good	6	11
Fair	8	10
Bad	14	4

The number of workers available to accept new tasks increased during the gamification process. The workers who were categorized as Good increased from 6 to 11, and the workers with a minor availability had a significant decrease. The results obtained are in line with the data collected before the gamification; at that point, 50% of the workers were not motivated to accomplish their tasks. According to Table 5, only 20% of the workers remained unmotivated.

We also attempted to evaluate worker motivation from an external view (engineers, trainees, office worker and others). To do this the Productivity Emblem was created; it is a prize awarded to workers when someone understands that his productivity is worth it. However, the participation of the external workers was not satisfactory; only the trainers participated in the process.

With the objective of evaluating worker motivation during the game, a survey was applied to eleven of them, chosen randomly. The results are shown in Figure 9.

From this research, we can infer that most of the workers felt motivated within the gamification process and even tried to change their behavior. All of them are motivated to win the cash prize.

6.3.4. Obstacles and Points of Improvement

The information flow regarding the weekly planning since its origin in the planning sector until it was presented to the workers has a very low transparency. Only the

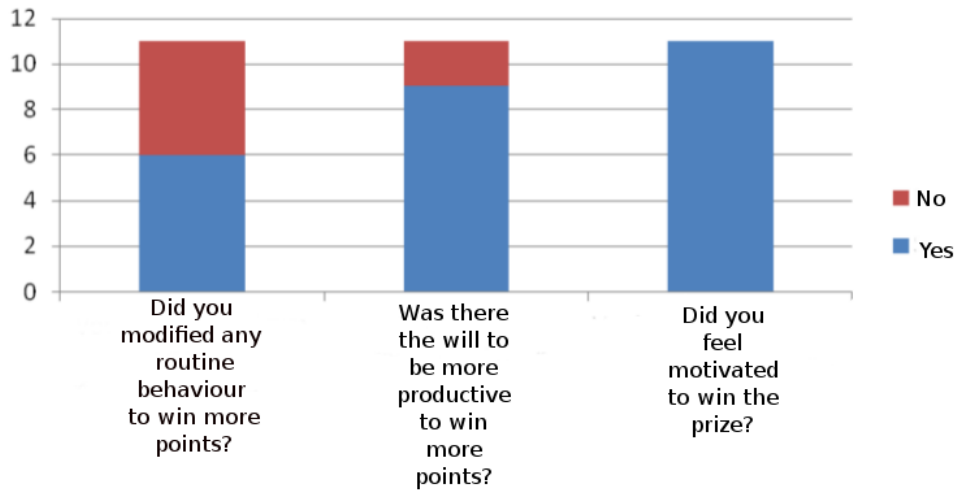


Fig. 9. Worker Motivation Graphic.

production managers and trainees have easy access to it. The gamification system is an alternative solution to addressing such a problem; however, other observed obstacles need attention, such as the following:

- The construction stakeholders (trainees, security technician) still need to perceive the importance of information transparency. This culture needs to change so that the gamification system has a long life at the construction site.
- Trainees are strongly encouraged to feed the systems with information collected from workers. This task should rely less on production managers because they are usually involved in more critical tasks.
- The calculation of the indicators proposed as rules should be periodically reviewed. There will always be a need to improve the calculus of rules so that they convey safety standards, discipline on the job and frequent attendance at the DDS.
- Workers in general require time to accustom themselves to the gamification system because their routine does not involve computers. The learning curve may be larger at those construction sites where information transparency is low.

6.4. Tool Performance Analysis

To analyze the tool performance, three criteria were used:

- Expressiveness and Communicability of Viewer Mode:* To perform this evaluation, we interviewed construction managers, trainees and engineer planners. We evaluated three topics: (1) Effectiveness of Information about the Planning of

- the Company; (2) Effectiveness of Information on the Ranking of Teams; (3) Effectiveness of Information on Workers.
- b) *Effectiveness of Visualization about Systems Screens for Workers:* Here, we express the (1) Understanding of Individual Information of Workers.
- c) *Understanding and Ease of Use of Administrator Mode:* In these criteria we show results on the ease of learning and ease of use of the administrator mode interface.

To analyze the information in this section, we used an average for each concept: Bad = 1, Poor = 2, Fair = 3, Good = 4, Excellent = 5. Thus, to calculate the average of each concept, we used these averages.

6.4.1. Expressiveness and Communicability about Viewer Mode

Expressiveness and communicability of the screens are important attributes in the usability evaluation of a system; they show how the submitted information is meaningful to the end user. Communicability is the ability of the interface to communicate to the user the logic design. In an expressive interface, the visualization is capable of expressing all data of interest to the user in context.

To perform this evaluation, an interview was conducted with the manager of the project, trainees and engineer planners. The opinion of the public is relevant to the search because information on weekly planning, available in the system, is generated and used by them in their daily work. What we want to check in this research is how the screen “Weekly Planning” effectively represents the planning information regarding the expressiveness and communicability criteria; see Figure 10:

Expressiveness and Communicability Week Planning Screen		Bad	Poor	Fair	Good	Excellent	Average
Expressiveness	1. Clarity in information architecture,			1		3	4.5
	2. Relevance of content,				1	3	4.8
	3. Simplicity				1	3	4.8
Communicability	4. Focus on worker				2	2	4.5
	5. Mapping				3	1	4.3

Fig. 10. (1) Effectiveness of Information about the Planning of the Company.

The planning screen was designated a EXCELENT concept, which corresponds to an average above 4.5; some of the questioned items are the following: 1. Clarity in information architecture, 2. Relevance of content, 3. Simplicity and 4. Focus on worker. Item 5, Mapping, was evaluated as GOOD (average 4.3), meaning that the mapping of information has failed in relation to communicability. Thus, the images and information presented on the screen can be improved to communicate more ef-

fectively. However, expressiveness and communicability of the Week Planning Screen display were evaluated as EXCELENT (average 4.6).

Second Figure 11:

Expressiveness and Communicability Ranking of Teams Screen		Bad	Poor	Fair	Good	Excellent	Average
Expressiveness	1. Clarity in information architecture,				2	2	4.5
	2. Relevance of content,				2	2	4.5
	3. Simplicity				2	2	4.5
Communicability	4. Focus on worker				2	2	4.5
	5. Mapping			1	2	1	4.0

Fig. 11. (2) Effectiveness of Information on the Ranking of Teams.

The teams ranking screen were designated as EXCELENT for some of the questioned items: 1. Clarity in information architecture, 2. Relevance of content, 3. Simplicity and 4. Focus on worker. Item 5, Mapping, was evaluated as GOOD (average 4.0), which reinforces the idea that the images or screen layout used for the presentation of the teams do not make visible the information on the team that the user thinks is important in the context. Expressiveness and communicability of the teams ranking screen were evaluated as GOOD (average 4.4).

Third Figure 12:

Expressiveness and Communicability Ranking of Employees Screen		Bad	Poor	Fair	Good	Excellent	Average
Expressiveness	1. Clarity in information architecture,				1	3	4.8
	2. Relevance of content,				2	2	4.5
	3. Simplicity				1	3	4.8
Communicability	4. Focus on worker				2	2	4.5
	5. Mapping			1	2	1	4.0

Fig. 12. (3) Effectiveness of Information on Workers.

It is observed that the workers ranking screen has the EXCELENT concept for some of the questioned items: 1. Clarity in information architecture, 2. Relevance of content, 3. Simplicity and 4. Focus of the worker. Although the four items reach the great concept, there is a relevance to the criteria Clarity in information architecture and Simplicity. The use of simple icons makes the screen easier to understand. Item 5, Mapping, was again evaluated as GOOD (average 4.0). Expressiveness and communicability of the workers ranking screen were evaluated as EXCELENT (average 4.5).

6.4.2. Effectiveness of Visualization about System Screens for Workers

This section was obtained by researching the understanding of the screens by the worker, observed during the presentations of the weekly planning and the final score.

Refer to Figure 13:

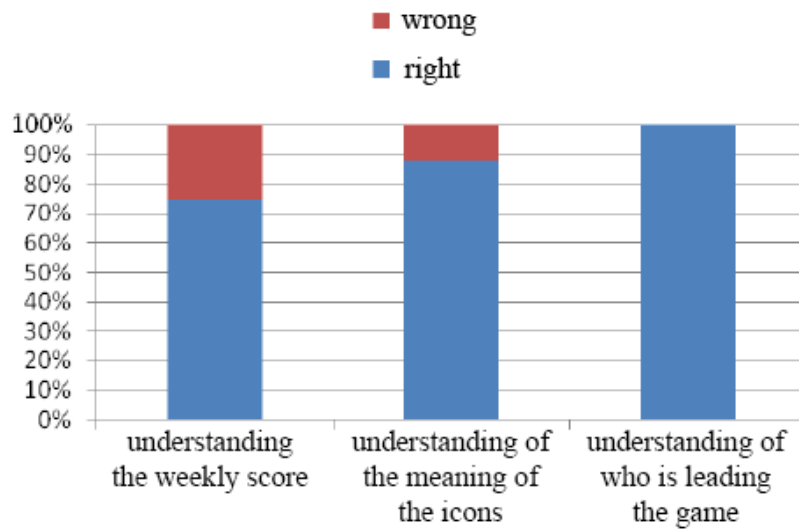


Fig. 13. Understanding of individual information on workers.

6.4.3. Understanding and Ease of use of Administrator Mode

The evaluation of the system administrator mode interface will focus on: learning facility and interface ease of use. To analyze usability, 5 testers were selected after testing to answer the questionnaire. Figure 14 shows the result of research into the understanding and ease of administrator mode use.

The administrator mode was evaluated as EXCELENT (average 4.6) on Item 3 and 4. In the other criteria, it was evaluated as GOOD (average near 4.0); however Item 9 had the lower score. This is because all the information for the game was inserted manually, making the insertion process repetitive. The understanding and ease of use of administrator mode was evaluated as GOOD (average 4.0).

6.4.4. Obstacles and Points of Improvement

In general, for the communicability and usability criteria, the developed interface for deployment of gamification at work can be considered satisfactory for what it claims to do, which does not rule out the possibility of improvements in future releases. There are some points that can be improved upon, such as the following:

Understanding and Ease of use	Bad 1	Poor 2	Fair 3	Good 4	Excellent 5	Average
Understanding / learning the system			1	3	1	4
Use of the system				3	2	4,4
Functionality and ease of system memory				2	3	4,6
System efficiency to what it claims to do			1		4	4,6
Ease of errors by the system			2		3	4,2
Ease of system navigation			1	2	2	3,8
User satisfaction with the use of the system			1	2	2	3,8
Ease of insertion of planning information			1	2	2	3,8
Ease of insertion of employee information			2	1	2	3,4

Fig. 14. Understanding and Ease of use of Administrator Mode.

- Regarding the expressiveness and communicability of the visualization of system screens: Need to improve weekly planning texts and improve the images displayed on the screens.
- On the effectiveness of the visualization of system screens for workers: The building construction worker who performs service independent of computing needs time to become familiar with the visualization of information.
- Regarding the understanding and ease of use of administrator mode: Need to review the data entry process of planning and worker information.

7. Conclusion

This paper presents a gamified web system to disseminate and support short-term planning and management in a civil construction site. The system goal is to support weekly planning and review of individual and team performance on construction sites based on principles of visual management and gamification. Besides increasing the visibility of weekly planning, the system displays rankings of most productive team and workers based on the fulfillment of their tasks. According to results from evaluation, the system opens up a new and important tool for improving transparency in the workplace as well as engage workers in their tasks. As a future work, we plan to develop a mobile interface for the system so that users can check their advances from their own smartphones and review the efficiency of the adopted gamification rules.

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