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Introducing Gamification in the AR-Enhanced Order Picking Process: A Proposed Approach

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Abstract: In the last decade, the Industry 4.0 concept has introduced automation and cyber-physical systems as the core elements of future logistics, supported by an array of technologies, such as augmented reality (AR) providing the necessary support for the digital transformation of manufacturing and logistics and the smartification and digital refinement of traditional pre-Industry 4.0 processes. This paper studies the influence and the potential of gamification techniques in supporting innovative Industry 4.0-enhanced processes in the contemporary warehouse work ecosystem. Gamification in the workplace aims to motivate the employees and increase their involvement in an activity, while at the same time creating a sense of an everyday different experience rather than a set of repetitive and monotonous tasks. Since the design of such a system is a complex process, the most widespread design frameworks are studied, and the emphasis is on the principal game elements and their connection to mobilization mechanisms. Finally, an initial proposal of a gamification framework to support the AR-enhanced order picking process in contemporary logistics centers is provided with an emphasis on the mechanics of a fair and functional reward system. The proposed approach aims to showcase the potential alignment of business processes to human motivation, respecting the differences between tasks and the workers' cognitive workload.

Keywords: Industry 4.0; gamification; augmented reality; logistics; digital transformation

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1. Introduction

The development of technology and Industry 4.0 has significantly affected the supply chain sector. The digital transformation of processes and ensuring the availability and reliability of information along the value chain are both issues of paramount importance for companies aiming to keep up with the rapid technology developments emerging in the scientific areas of machine-to-machine automation and cyber physical systems [1]. This journey, however, is tough and requires a full understanding of the steps needed to be made. Hence, there are four pillars on which a business must count as follows: (i) the data collection, utilization, and control through new technologies (artificial intelligence and augmented reality); (ii) new methods of physical transportation (autonomous robots and drones); (iii) digital platforms connecting the distributors to the warehouse employees; and (iv) the development of new products using three-dimensional (3D) printers [2]. In any case, a business can benefit from the digital transformation of the supply chain, as it facilitates the communication and data exchange between the stakeholders in real time. Moreover, it promotes the transparency of the organization and a more efficient control on the processes, resulting in the improvement of the overall performance. Finally, yet importantly, it redounds on the reduction of errors and enables a decision-making system based on supply and demand [3].

One of the key new technologies that comprise Industry 4.0 is augmented reality. As a term, it lies closer to reality than to virtuality and is governed by the following three main characteristics: (i) it combines the physical world and the virtual elements, (ii) it enables real-time interaction, and (iii) virtual elements are registered in 3D [4]. Nowadays, many companies have adopted AR technology and capitalize on its potential to improve their performance, while giants of companies, such as Google, Microsoft, and Apple, have launched their own applications and devices. Augmented reality is widely accepted because it enables information visualization and reinforces the perception of reality. Moreover, it simplifies daily routines by keeping the data needed for the accomplishment of a task in the user's field of view.

Another attempt to leverage the technology advancements is the implementation of gamification in the workplace. This term stems from the video game industry and it widely differs from the concept of a plain game, despite their mutual roots. Gamification is defined as the use of game elements in a non-game context [5]. The differentiator between the two terms is that the game is nonproductive, fun, and does not have a predefined outcome. However, gamification applies the game morals in order to change the user's behavior in non-game contexts, while also aiming to increase his participation and engagement [6–8]. The integration of game elements in the workplace results in an increase in productivity, employees' engagement, and their retention, as well as the promotion of innovation in general. Thus, game elements keep employees motivated with a new knowledge and encourage competition among peers, while rewarding and recognizing those who excel.

Order picking summarizes the on-time delivery of the right quantities of goods for internal or external customers at the lowest possible cost. All tasks related to this process are considered to be labor intense and repetitive [9,10], with strict time constraints, while minimizing the picking errors. Workers are usually demotivated because of the monotony of order picking and they end up losing focus, feeling stressed, and dissatisfied [11–13]. Striving to solve these problems, the majority of companies have already introduced monetary motivation strategies, under the belief that this is the only way to satisfy workers. While most of the optimization approaches focus on the matter's technical aspect, they tend to overlook humans' behavior and needs. To that end, the logistics industry began integrating gamification techniques. However, managers should seriously consider all factors that contribute to human motivation, i.e., progress, rewards, feedback, and reinforcement [14,15]. In addition, they assume that the use of a gamification system could lead to an increase in workers' productivity and spirit, while also creating a pleasant workplace and promoting healthy competition.

However, it is still early to determine if and how gamification fulfills its purpose, meaning that more research is required on developing methodologies and theoretical bases concerning the accumulation of the right knowledge [16,17]. Even though there are empirical studies on gamification's impact on human motivation and behavior in general, the outcomes depend on contextual factors, such as the circumstances, the users' characteristics, and their intentions [18]. Furthermore, the literature on gamification mostly focuses on the domains of education, crowdsourcing, health, and wellness [16,17,19]. Over the past few years, logistics have gained more attention from researchers, where studies try to investigate the effect of individual game elements [20–22], implement gamification in order picking [23], investigate the acceptance from workers [24,25], and try to improve work competences [26].

Even though there are studies that have investigated the potential of technology acceptance and the effect of specific game elements or a combination of them on human motivation, a lack of holistic approaches regarding the design of gamified systems is undoubtedly observed. The purpose of this study is to design a theoretical basis for a gamification system, focusing on human motivation and the development of a fair point system in warehousing processes and especially order picking. By laying the foundation for gamification integration in logistics, the goal is to radically change the perception of the workload or the nature of one's work. Managers need to understand the ways they can keep their workforce motivated and less dissatisfied through the adoption of a human centric technology.

This paper is organized in six discrete sections. In Section 1, we introduce the basic concepts and states the objectives of this paper; in Section 2, we present the necessary theoretical background; in Section 3, we present an approach for the introduction of gamification in a real-life industrial scenario; in Section 4, we present the results of the proposed approach in the exploratory case described in the previous section, followed by a critical evaluation of its validity, completeness and potential for further application in Section 5; finally, in Section 6, we outline the main conclusions of the study, followed by a discussion on its limitations and prospects for future research.

2. Theoretical Background

In a highly interlinked world, both distribution and warehouse processes constitute critical factors of the supply chain management. Even though most of the inhouse logistics processes are automated, there are still some that depend on the human factor, concerning the decision, experience, and expertise. One of them is the order picking process, where tasks are monotonous and repetitive, requiring high concentration levels from the employees. Thus, the implementation of AR facilitates the information exchange between humans and machines, reduces the workload, and simplifies the daily routine. In addition, the logistics industry tends to apply gamification techniques to psychologically satisfy the workers, given that warehouses are just as good as their employees [27]. However, the gamified system must not intervene with the execution of daily tasks. The main goal is to change the perception and the experience of the worker and not to radically alter tasks overall.

2.1. Order Picking Support Systems

Order picking is one of the most critical and costly warehouse processes. To this day, there have been many tools developed to support operators and increase both quality and productivity. Hence, warehouses apply mobile and steady order picking support systems (OPSS), primarily Pick-by-Vision [28], combining the human flexibility of workers and technological accuracy. These systems create a link between the operator and the warehouse management system (WMS) with constant data exchange. This link allows managers to continuously monitor the order picking process and the respective key performance indexes (KPIs), i.e., time and accuracy [29–31]. In fact, studies state that the introduction of IT systems in order picking can improve productivity up to 30%, and the operational flexibility as well [10,32]. In order to support pickers, the IT devices used, head-mounted displays (HMDs) or smart glasses, provide and acquire data depending on the environment, such as the location of a product or the picking confirmation. Then, these data are transmitted to the WMS, which updates the inventory and feeds the OPSS with the information of the next pick in real time. The key advantage of a such system is the ability of the operator to work without using their hands, as the information is displayed on their field-of-view, keeping their eyes solely on the routes and allowing the operator to focus on the process [33]. It is also interesting that the majority of support systems inform operators about the errors made during the picking process, verbally or visually.

The Pick-by-Vision system uses AR technology to support the order picking process. Operators wear special devices, displays or glasses, for the superposition of the real world with the virtual objects [34]. The display enables the visualization of the task's information right on the picker's field of view, while the WMS provides real time data. Depending on how sophisticated the system is, the device can even navigate the user in the warehouse's aisles, taking into consideration his current position or visualizing picking information in textual format. Pick-by-Vision, in essence, is shown to reduce errors up to 75% and execution time up to 30% as compared with paper-based systems [35]. Augmented reality is basically used to broaden the worker's field of view, while ensuring higher visibility, flexibility, and guidance. In addition, operators are more comfortable, and it is easier for them to pay more attention to their task, as they avoid making unnecessary head moves. According to the activities related to order picking, the use of AR technology is summarized as follows: inform pickers about their next allocated tasks, display pictures and details of products to be picked, display storage location and picking route, give information to prevent congestion in aisles, scan and highlight items to be picked and their respective physical locations, monitor pickers' condition and performance [36].

However, during the implementation of an OPSS, decision-makers need to take a close look into AR's restrictive factors, besides its high cost. First, devices' batteries usually do not last long shifts and operators need to charge them once or twice a day, and processors overheat. Sometimes, wearable devices are not comfortable, as workers experience headaches and eye fatigue, implying the need for a better and more ergonomic design. Meanwhile, studies have shown that pickers may feel their privacy is invaded, especially if they are constantly wearing devices with attached cameras and microphones [37]. Another limitation that needs to be overcome is the development of user-friendly AR applications, in total contextual harmony. Therefore, it is necessary to take into consideration the basic principles of work design and cognitive ergonomics, emphasizing the factors associated with cognitive workload. These are the users' personal preferences and the information they need, depending on their experience and skills. The first factor refers to the ability to customize both colors and font size to minimize the perceived workload, whereas the second factor refers to the development of different support levels for pickers, regarding the task's current state. This means that highly experienced pickers may be overwhelmed from the information overload while using the same support levels with younger, less experienced co-workers [38]. The simplest motor processes, such as walking, under normal circumstances, are not significantly affected when executed at the same time with other cognitive demanding tasks, because they do not rely too much on the cognitive resources. Nevertheless, there are tasks that require full employment of the cognitive resources, hampering the aforementioned motor processes [39]. In conclusion, the connection between tasks' cognitive workload and pickers' cognitive skills affects their overall performance, which is critical for the efficiency of order picking [38]. Therefore, having considered the basic principles of work design and cognitive ergonomics, it is essential that the AR application takes into account operators' skills, provides them only with the required information, and is consistent and relevant throughout the process overall.

2.2. Gamification

Gamification is not just a buzzword, as it has great potential in the workplace if implemented properly. To gain a better understanding, it is important to study how human psychology works and in which ways workers can be motivated. Most gamification experts mention game experiences, where players feel invincible, think outside of the box, and show great persistence in order to excel and, by extension, be rewarded. In fact, people are considered to project the best version of themselves while playing, as they team up with others, work together towards a shared goal, and generally suppress their negative feelings. Therefore, the ultimate goal of gamification is to integrate the game experience to real world contexts and problems.

2.2.1. Human Psychology

Psychology has a strong presence in every task requiring reflection, behavior models, and motives. In fact, gamification is based on 75% psychology and only 25% technology [40]. While analyzing the human behavior, it is useful to identify the two kinds of motivation, i.e., intrinsic and extrinsic. The first, intrinsic motivation, refers to humans' voluntary engagement in an interesting task, leading their own personal growth. In this case, people experience satisfaction because of the completion of the task, maintain their well-being, and improve their efforts' quality, creativity, performance, and efficiency. On the other hand, extrinsic motivation refers to the behaviors incited by external rewards, such as money or worktime [41], which are short-term motivational measures. Moreover, they usually do not guarantee a person's enhanced performance and act at the expense of intrinsic motivation [42]. Hence, it is crucial to ensure that the gamified system promotes and relies on intrinsic motivation. According to Fogg's behavior model, the performance of a target behavior is more likely to be increased if motivation, abilities, and triggers co-exist at the same time and over a predefined threshold [43]. However, it is necessary that the person is provided with the right trigger at the right time in order to associate it with the required behavior.

The most predominant motivation theory is the self-determination theory, regarding humans' innate tendency to evolve and satisfy their basic psychological needs, i.e., autonomy, competence, and social relatedness [42]. Autonomy is about volition, constructive, and informative feedback, as well as the decision-making process, depending on one's values and interests [44,45]. Competence is the need to participate in challenges and feel efficient and productive, while essentially interacting with the environment [46]. Lastly, social relatedness refers to a person's feeling of belonging and communicating with another group of people, through competition, cooperation, and communities [42]. Gamification is also linked to the flow theory, according to which "flow state" is achieved while being fully immersed and engaged in the process of an activity, losing all sense of time, feeling enjoyment, stress-free, and confident [47]. However, in order to experience the flow state, both the difficulty of a task and one's abilities have to be balanced. If the task is more difficult than the person is competent, the result is overwork, lack of control, and higher stress levels. On the contrary, if the person is more competent that the task is challenging, the result is loss of interest, boredom, and rejection of the system. However, there are nine dimensions of psychological flow which define a user's best experience on the whole as follows: (i) difficulty-competence balance, (ii) action-awareness merging, (iii) clear and feasible goals, (iv) unambiguous feedback, (v) focus on the task given, (vi) sense of control, (vii) temporary loss of self-consciousness, (viii) distorted sense of time, and (ix) autotelic experience [40,48].

2.2.2. Motivational Mechanisms

Within the scope of motivational theories, researchers have explained the orientation, persistence, and intensity of target behaviors and have noted the following six basic dimensions of psychological needs related to gamification: the trait perspective, the behaviorist learning perspective, the cognitive perspective, the perspective of self-determination, the perspective of interest, and the perspective of emotion [49]. These dimensions do not override each other, but they do emphasize different frames. Thus, motivational mechanisms play a two-fold role, i.e., one to inform on the impact of game elements to one's motivation and one to contribute to the proper design of the gamification context. The trait perspective states that motives are personal features that affect one's behavior, regardless of different situations and times. These features are the achievements and the need for power and relatedness [50]. According to the behaviorist learning perspective, motives result from past experiences, i.e., positive or negative reinforcement. Hence, people are motivated when they receive positive feedback or rewards. On the cognitive perspective, motivation is based on means-ends analysis, considering users' expectancies and consequences of their actions and their perceived value as well [51]. Thus, it is important to provide clear goals and highlight their consequences, while promoting mastery orientation. The perspective of self-determination focuses on the satisfaction of the three principal psychological needs, whereas from the perspective of interest, the key motivational factor is a user's personal preferences of general satisfaction and enjoyment. Finally, the perspective of emotion emphasizes the impact of emotions on one's cognitive and motor processes. Therefore, players are more likely to be motivated when the system boosts their positive feelings.

2.2.3. Gamification Design Frameworks

The development of a gamified system requires meticulous planning. Each phase of the process should be linked to a target goal and facilitate its fulfillment, while keeping in mind that people solve only the problems that affect them and, by extension, become more efficient and productive. Hence, the gamification design should be humancentric, so that the problem's resolution is an interesting and pleasant experience for the user. The most widely known design processes are the 6D framework [45] and Octalysis [52]. The first design consists of six key steps/premises from concept to product, whereas the later design focuses on the eight core drives of human motivation.

According to the 6D framework, the first step is to define and prioritize all business objectives that align with users' needs or even create new ones they may want to accomplish. Meanwhile, all mechanisms acting as means rather than ends are restricted and non-justified goals are kept off the design process. A similar method is followed in the next step of the framework as well, which is to delineate all target behaviors. In this case, it is essential to develop metrics for each of the behaviors and determine the respective winning conditions for the users. One of the most important steps is to describe the system's players, as an in-depth understanding of their characteristics is crucial to motivation's effectiveness. Thus, the following four typical players can be identified: socializers, killers, explorers, and achievers [53]. In order to maintain the game flow, it is necessary to devise activity loops, both engagement and progress. The engagement loop motives trigger users to perform a task, incited by rewards, leading to achievements, which then reinforce the motives anew [40]. According to the progression loop, players achieve their goals through a series of small challenges, instead of just one action. Hence, the gamification system should support different levels of difficulty and expertise, conforming to the player's journey and the paradox of the active user [40,54]. The next step of the framework is to add the fun element, as the system's point is to engage the user and keep him interested, whereas the last one is to deploy the appropriate tools, i.e., the game elements. During this process, it is important to determine which elements work best towards the goals' achievement through competition analysis and repetition.

Octalysis is a design process that optimizes human motivation, taking into account users' feelings and insecurities. The eight core drives are the following: (i) epic meaning and calling, (ii) development and accomplishment, (iii) empowerment of creativity and feedback, (iv) ownership and possession, (v) social influence and relatedness, (vi) scarcity and impatience, (vii) unpredictability and curiosity, and (viii) loss and avoidance. More specifically, epic meaning and calling refer to players' feelings of eclecticism, as they overestimate their competence, while devoting a lot of time to the gamified system. Development and accomplishment are about users' inner efforts to improve their skills, make progress, and overcome challenges. Empowerment of creativity and feedback describe the resolution process, where players express their creativity and monitor their progress. Ownership and possession primarily refer to the users' needs to upsize and improve their belongings. Social influence and relatedness express the innate human psychological need to be part of a community and interact with others. The main characteristic of scarcity and impatience is a player's persistent desire to acquire something they cannot have and keep returning to the system. Unpredictability and curiosity are harmless motivational mechanisms, according to which the user is inquisitive to explore the system's flow, whereas loss and avoidance are based on the suppression of negative events, such as losing progress. However, it is not necessary for a gamified system to consist of all eight core drives, but to properly implement the chosen ones. All core drives are graded on a scale of 0–10, depending on a designer's personal judgement, data and experience flows. Then, each number is squared, and their sum constitutes the system's overall score.

2.2.4. Game Elements

As mentioned before, game elements are the deployment tools of gamified applications. The most widely known and commonly used are the following: points, badges, leaderboards, performance graphs, meaningful stories, avatars, and teammates [5,45].

Points are the most basic game element, and they are usually gained after the successful completion of an activity. They provide a visual representation of players' progress [5,45] and continuous and direct feedback, addressing their need for competence [48,55,56]. They can also be considered to be metrics for a target behavior and rewards as well [57]. Badges are the visual representation of players' achievements, symbolizing their worth and level [45,58]. They can also serve as goals, if the users are aware of the respective prerequisites, or as virtual status symbols, satisfying the need for social relatedness [40,45,59]. Even though they provide feedback related to a player's performance, their collection is not mandatory, and they do not add up to the system's narrative. However, they can affect players' behavior, pushing them to follow certain paths or to take part in challenges, so as to collect the relative badges. In any case, their unlocking may depend on the number of total points collected or the performance of specific activities. Usually, they are color/text coded, i.e., bronze-silver-gold, and all players have equal chances for obtaining them, given that they do not know the collection conditions.

Leaderboards are used to rank all players' performance from best to worst based on given criteria [60]. They serve as competitive indicators, as players tend to compare their own progress to their teammates' [55,56]. However, the impact of leaderboards is ambiguous, as they can either benefit or harm intrinsic motivation. They can be motivators only when the player is close to the next level or position. Otherwise, if a player ranks low on the leaderboard, they are likely to be discouraged because of the intense competition and social pressure to increase their engagement levels [45]. Performance graphs provide information about player's performances throughout the game. They also set up personal standard references, enabling players to focus on their growth and become more competent [55–57]. On the contrary, meaningful stories are not associated with players' performances. The narration frame contextualizes system's tasks and characters, by extending their meaning beyond the simple quest for points and achievements [54]. Avatars are the players' unique visual representation, as they choose or create their own image and profile [45,54], by adopting a new identity on the game and becoming active community members [58]. Finally, teammates can be either real or virtual non-play characters and their goal is to promote disputes, competition, and cooperation [54].

Having identified the key game elements, it is highly important to associate them with the six motivational mechanisms in order to facilitate the design process and the deployment of the appropriate tools. Points are connected to the behaviorist learning perspective and the perspective of interest, as they provide direct positive reinforcement and virtual rewards. Badges are connected to the trait and cognitive perspective, as well as the perspective of self-determination and interest. More specifically, they express the need for success, competence, social status, and relatedness, while also providing clear goals. Leaderboards are associated with the trait perspective and the perspective of self-determination, because they satisfy the need for competition, achievements, competence, and social relatedness. Moreover, performance graphs are linked to the cognitive perspective and the perspective of interest, as they provide clear goals, mastery orientation, and constant feedback. Meaningful stories boost the need for autonomy and positive feeling. Hence, they are connected to the perspectives of self-determination, interest, and emotion. Avatars satisfy two of the key psychological needs, i.e., autonomy and social relatedness, while increasing positive emotions and indicating their association with the perspectives of self-determination and interest. Finally, teammates are linked to the trait perspective and the perspective of self-determination, because they promote both competition and cooperation and satisfy the need for competence and social relatedness at the same time.

2.3. Related Work

Studies have investigated the effect of all the aforementioned game elements on human motivation, both individually and combined. One study showed the positive effects on human performance and motivation, by deploying a set of game elements (points, badges, leaderboards, performance graphs, avatars, and meaningful stories) in a gamified version of an order picking setting and handing workers out questionnaires concerning the satisfaction of their key psychological needs [26]. In fact, workers on the gamified setting worked faster and made fewer mistakes than the others did. A second study examined the effects of different combinations of game elements in order to investigate the satisfaction of psychological needs, using an online order picking simulation [61]. In that context, workers were challenged to process orders from a bird's eye perspective. The first combination of game elements consisted of points, badges, and leaderboards, while the second combination consisted of avatars, meaningful stories, and teammates. The groups were both compared to one that did not use any game elements. According to this study, the first group seemed to have a greater impact on motivation. Moreover, a third study focused on the use of game elements that provide information on the user's success and questioned the workers about the acceptance of those feedback related features [24]. The questionnaire included personal parameters, such as individual perceptions of motivation, job characteristics, and gamification in general, where the results highlighted the positive effect of feedback and the need to raise acceptance and awareness regarding gamification.

However, research on the potential of augmented reality combined with gamification techniques in order picking is now under development. Using an order picking application for Microsoft HoloLens, and then handing out questionnaires, an experiment was conducted among workers to test the effect of leaderboards and badges on human motivation and tasks' completion time [62]. On one hand, leaderboards had a negative impact on the experience of competence due to competition but lead to faster execution times. On the other hand, badges were not significantly related to one's performance. Moreover, the results highlighted the influence of demographics and personal characteristics, such as age, gender, and height. Investigating the acceptance of both technologies, i.e., AR and gamification, in order picking operations, a questionnaire-based survey was conducted to managers and workers from large distribution centers in Greece [25]. As the questionnaire focused on the introduction of AR-enhanced order picking, gamified order picking, and AR order picking enhanced with gamification, the results were interestingly positive from both managers and workers concerning the practicality and the support of order picking via wearable AR devices that integrate gamification techniques. The combination of these two technologies seems to be a perfect match, increasing productivity and job satisfaction, as well as smoothing the "burnout", which is a major concern that comes along with the introduction of a new technology.

3. A Gamification System Proposal

Implementing the gamification techniques on an AR-enhanced warehouse can be a complicated task, as there are many concurrent objectives, metrics, and factors that need to be considered. However, the proposed gamification system focuses on the order picking process, which is the most repetitive and monotonous one. The key objectives of a modern warehouse can be listed as follows: (i) high efficiency, (ii) increase workers' engagement and retention, (iii) cost and time reduction, (iv) error minimization, and (v) effective HR management. Moreover, the necessary KPIs are productivity and picking quality. Taking all these into account and upon research, the proposal consists of the analysis of the game elements to be deployed and the accompanied reward system. More specifically, the chosen game elements are points, badges, leaderboards, performance graphs, and avatars and their implementation on the system is based on proven effectiveness, according to empirical studies [48,55,56,58,59]. This proposal is based on two modules, i.e., AR and gamification, integrated in the WMS and connected through an API [63]. In essence, the AR module is the OPSS, while the gamification module provides the worker with an unprecedented work experience. In this case, we focus more on the gamification design rather than the OPSS.

A meaningful gamification design requires the development of a fair point system, where players will not feel left out despite optional participation in the system. Building on that, all players should have equal chances to gain points, considering each task's special characteristics. However, only the processes that are timestamped can be included in the system. Hence, job rotation among workers is required, so that everyone can perform all tasks and collect the respective points. Furthermore, workers should be aware of the way points are attributed, and then make an informative decision on whether they want to participate or not. In this context, the most fair and efficient way to attribute points is based on the task's standard time. For this purpose, six different scenarios were developed to test the variance between workers' daily collected points, under the following reductive assumptions: (i) there are 15 tasks and 25 workers in the warehouse, (ii) each worker performs each task in a certain amount of time whenever it's allocated to him during the day, and (iii) instead of working a full eight-hour shift, workers are allocated approximately 150 tasks daily, without having a break.

The point system is designed on a theoretical level, meaning that the number of tasks is arbitrary, as well as their respective standard times. Three groups of five tasks are formed and the first one, i.e., tasks with a step of 15 s, refer to the order picking process, while the other two, i.e., tasks with a step of 30 s, refer to the rest of the warehouse processes, such as loading and palletizing. Moreover, the allowed range of execution times is defined, by attributing "tolerance" percentages to every group of tasks, depending on their average standard time, i.e., 10%, 20% and 30% respectively. In addition, the daily execution times are determined by using the RANDBETWEEN function on MS Excel and the task's upper and lower bound, as shown in Table 1. In this way, every alteration made on the spreadsheet causes the execution times to change, facilitating the monitoring of a worker's performance on every task. However, it is highly important to clarify that all scenarios use the exact same data and in the same context, allowing us to make the necessary comparisons. The allocation of tasks is defined by using the RANDBETWEEN function and their identification numbers, while all execution times are sought by using the VLOOKUP function. Time is measured in minutes and the total daily points are the sum of each task's collected points. In all scenarios, the task's standard time turns automatically into points with every allocation.

Table 1. Tasks, groups, standard times, and allowed range of execution times.

ID No.	Group	Tolerance Percentage	Standard Time (s)	Min Allowed Execution Time (s)	Max Allowed Execution Time (s)
1	1	10%	30	27	33
2	1	10%	45	40.5	49.5
3	1	10%	60	54	66
4	1	10%	75	67.5	82.5
5	1	10%	90	81	99
6	2	20%	120	96	144
7	2	20%	150	120	180
8	2	20%	180	144	216
9	2	20%	210	168	252
10	2	20%	240	192	288
11	3	30%	270	189	351
12	3	30%	300	210	390
13	3	30%	330	231	429
14	3	30%	360	252	468
15	3	30%	390	390	507

The first scenario is based on the assumption that workers gain points only when they are faster than the task's standard time. Thus, the number of points collected is formed by the standard time plus the difference between standard and execution times. In the second scenario, the aforementioned difference of times is added up or subtracted from the standard time, depending on whether the worker is faster or slower than the standard time, respectively. However, the third scenario is an attempt to promote positive reinforcement and attenuate the negative one, while testing the impact of times' difference.

More specifically, this difference is multiplied by an arbitrary factor, which is adapted properly. In case the worker is faster than the standard time, the factor is 1.5, otherwise it is 0.5. Similarly, in the fourth scenario, the factors are 1.25 and 0.25, respectively. The fifth scenario follows a different approach on the difference between standard and execution times, as it deals with their percentage change. Thus, it takes into consideration the value of time, meaning that workers should not be rewarded equally while performing different tasks where there is a significant variation between standard times. Hence, in the fifth scenario, the percentage change of times is added up or subtracted from the standard time whenever the worker is faster or slower than it, respectively. Finally, in the sixth scenario, points are attributed only when the worker is faster than the task's standard time, where the percentage change is added up.

Furthermore, badges are of equal importance as points and cannot be excluded from the gamified system. Therefore, it is essential to pay close attention to their design process. Each task performed can be a distinctive category of the warehouse processes and, by extension, every category should be represented by its own badges. Every task, such as order picking, can be further divided in zones, if required, namely picking at the first floor, picking at the second floor, picking with the put2light system, etc. There are three key metrics in every zone, i.e., speed, the number of times the task is allocated to the worker, and the amount of total goods handled. Then, all metrics are subcategorized to define the different levels of expertise, i.e., bronze, silver, and gold. Finally, there is also another set of badges, totally independent from the previous ones, for the employee of the month, where the respective data will come from the total number of points collected. A typical Badges' Structure, as described above, is presented in Figure 1.

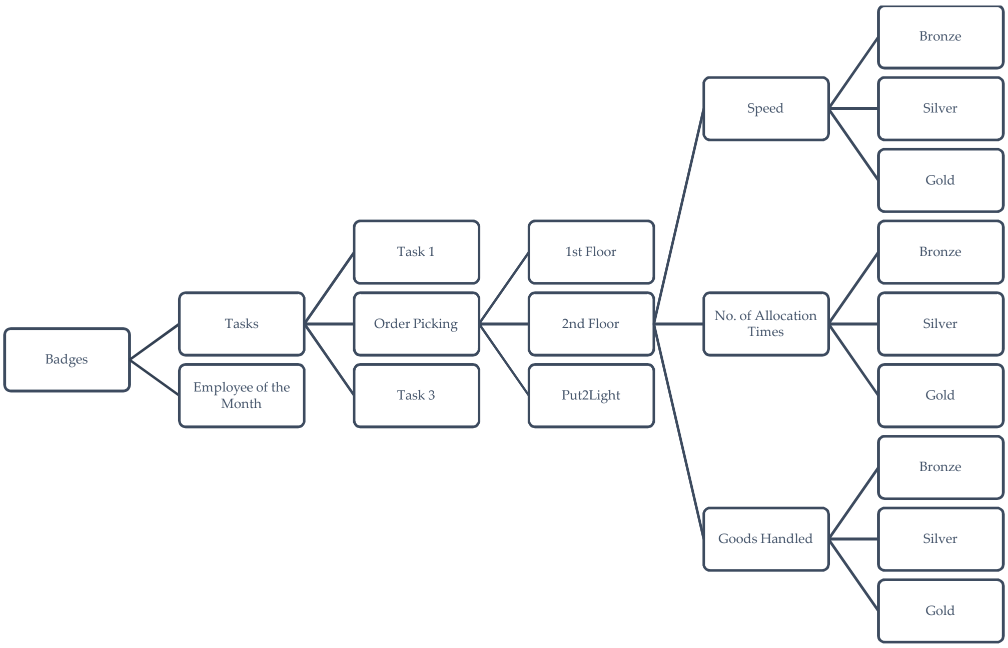

Figure 1. Typical badges' structure.

The next key game element is leaderboards and, in this context, they are not used on a daily basis, as they are competition indicators. Hence, they are only accessible and visible to the administrators, in order to facilitate the decision-making process and the evaluation of the KPIs. Workers rank on the leaderboard based on their collected points, meaning that managers can easily track their progress and performance. Thus, those in lower positions can be further motivated or engaged, whereas those in higher positions can be further rewarded. Performance graphs enable players to set their own standard references and keep track of their performance. For this purpose, there are progress bars and reports for specific time periods, so that workers can decide where to focus next. Lastly, avatars facilitate players' profile development and therefore is is necessary for workers to sign into the system. Hence, the profile is updated in real time and players decide what to share with the community.

Nevertheless, gamification should also consist of a tangible reward system, in order to provide a meaningful participation for players and satisfy their innate needs at the same time. In fact, rewards have a similar effect on motivation as badges [64]. Users can redeem their points in a virtual marketplace that fits their performance. Thus, points with no other prerequisites categorize the rewards, while their value is equivalent to a player's level on the gamified system. This means the worker is aware that it is feasible to claim a reward, though he needs to put an effort to it. More specifically, on the one hand, there is no point putting a "high price" of redeemable points on a reward, as it can harm intrinsic motivation. If so, workers would end up working hard, expecting a reward that would keep not coming, resulting in their demotivation after all. On the other hand, rewards should not have a "low price", as it would be really easy for the workers to claim them, leaving no room for any further improvement and, by extension, losing interest in the gamified system. In any case, rewards should not be linked to one's work time or salary, as these are means of extrinsic motivation. Examples of proposed rewards for a virtual marketplace are the following: the ability to buy company products or affiliated ones at a discount or by redeeming players' points, gift cards and coupons, gym subscriptions and tickets for recreational activities; access to limited edition or customizable products, airplane tickets and travel offers; redemption points for fuel buying; and multiple-points days of work. These kinds of rewards are based on typical loyalty and rewards programs run by large corporations. However, it is important for the managers to make sure they are able to provide the rewards to the system's users all the time.

4. Results

In order to determine which scenario is most fair, it was necessary to find, and then compare the total daily points of the 25 workers. Hence, the following values were defined: maximum total points, minimum total points, the range of collected points during the day, the mean value, and the standard deviation. However, the addition of standard time turned into points with every allocation was vital; as it was observed that without it, players could end up even losing points during a shift, indicating that the design would focus on punishment rather than rewarding. Looking close into the six scenarios, it was found that the fifth scenario one was the most fair and optimal, as it constantly had the smallest standard deviation. The use of the percentage change of execution and standard times explains this outcome, as it takes into consideration the differences between tasks and their characteristics, as well as time's value. Hence, the small standard deviation represents workers' equal chances to gain points depending on their performance in an objective and fair way.

However, it is noticeable from the information presented in Table 2, that the differences among Scenarios 2, 3, and 4 are insignificant as compared with the other scenarios. In fact, the arbitrary factors in Scenarios 3 and 4 do not seem to affect positive or negative reinforcement as expected. Moreover, Scenarios 1 and 6 are considered to be harsh, given that the respective standard deviations are two to six times bigger than those of the other scenarios.

Table 2. Typical scenarios' data.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Min Points	72,383	1962	209,592	211,854	204,861	3537
Max Points	514,017	292,883	310,033	304,033	278,159	248,539
Range	441,634	96,683	100,725	92,179	73,298	213,169
Mean Value	282,067	239,309	25,346	253,031	238,067	131,329
Standard Deviation	106,828	23,029	24,737	22,318	17,077	52,192

As mentioned before, all scenarios use the exact same data in the same context, which allowed us to make comparisons between them. However, in a real order picking setting, the AR API would provide the respective data, updating both the gamification module and the WMS. Thus, workers would use wearable devices such as smart glasses to scan the products and confirm the collection, generating the required timestamp and by extension the percentage change of execution and standard times.

5. Discussion

The proposed gamification framework is theoretical, and therefore it would be worthwhile to explore its practical application. However, it is safe to assume it could be beneficial to a real modern warehouse, primarily due to the use of tasks' standard time. The data are considered to reflect reality, although there could be some deviations because of the reductive assumptions made during the design process and arbitrary definition of standard times. It is obvious that workers do not perform an allocated task in the same amount of time every time throughout the shift, although, under normal circumstances, execution times are not expected to be significantly different, as the predominant scenario consistently displayed the smallest standard deviation on the total daily collected points between workers. Moreover, given the assumption that workers perform a fixed number of tasks on a daily basis, they do not end up working equal hours overall, resulting in different reward levels. Thus, workers who surpass their eight-hour shift could be further rewarded with extra points, as they work overtime.

However, it is also important to highlight the differences between this study and the previous ones. First of all, the development of the point system customized to a warehouse's processes and their standard times, rather than focusing solely on the completion of a task or the achievement of a productivity goal [63]. Furthermore, the proposed framework does not deal with picking errors, which is left for future research and work. Badges are not linked to picking specific goods or walking a predefined distance [62], but they are related to goals depending on metrics, such as speed and expertise. Another interesting difference is the use of leaderboards on a managerial level, in an effort to limit the negative impact of competition on intrinsic motivation. In previous studies, leaderboards were visible to workers and managers via a big screen on the warehouse, displaying the workers' ranking [62,63]. Meanwhile, the use of performance graphs and avatars reflects the typical use case, including progress bars, reports, and the necessary profile development.

In any case, the gamification system could be further extended by deploying more game elements or by altering the use of the current ones. For example, challenges and meaningful stories could be also implemented. A typical challenge would be to determine daily productivity goals for the warehouse on the whole, or the worker in particular. However, it is important to exclude all kinds of punishment if the worker does not achieve the goal and reward him with extra bonus points otherwise. As far as meaningful stories are concerned, these are dynamic game elements and require constant updating to keep players engaged. Thus, they cannot run for a long time. The addition of the aforementioned game elements could also alter the use of leaderboards by making them visible to workers during the run-time period of a challenge or a story. Players could see their ranking, while tracking their progress through the performance graphs.

6. Conclusions

The use of humancentric technologies, such as augmented reality and gamification, results in an increase in efficiency and productivity, while reducing a worker's cognitive workload and perception of monotonous and repetitive tasks. Most of the logistic processes aim for accuracy, smaller lead times, and more effective human resources management. In addition, appropriate information for workers is an overriding concern, as it accounts for the majority of errors made during shifts. Hence, Industry 4.0 and digital transformation facilitate the constant data exchange and flow towards all stakeholders, improving the overall organization's performance, transparency, and control.

Order picking is a vital process for logistics, accounting for the majority of the total warehouse operational expenses and it is considered labor intensive, repetitive, and monotonous. Under the cloak of digital transformation, most warehouses implement various support systems and primarily those are based on augmented reality, i.e., Pick-by-Vision. The OPSS is linked to the WMS in order to provide real-time data about the inventory and the necessary information of picking goods. Pick-by-Vision enables reduction of errors and execution times, because information is directly displayed in a worker's field of view. However, it is highly important to take into consideration workers' preferences and levels of expertise, to avoid fatigue and confusion.

In addition, gamification in the workplace could benefit both an organization and workers at the same time. It is a promising technology, facilitating the enhanced performance and engagement of workers, while keeping them motivated and psychologically satisfied. Hence, it leverages game techniques and experiences to change human behaviors towards the achievement of business objectives. Gamification creates a virtual world, where workers can be productive and have a fun time simultaneously. However, it is crucial to deeply understand how human psychology and motivation work, and then design a system that enables players' personal growth and pleasure. During the design process and especially the deployment of the appropriate game elements, it is important to consider their connection to the key motivational mechanisms. In any case, the system should not intervene with workers' daily tasks, avoiding an undesired disorientation from the actual goal. Moreover, players should receive constant feedback in a positive reinforcement form and be rewarded.

In general, all workers should have equal chances to collect points and badges. In the proposed gamification framework, a fair point system is developed based on tasks' percentage change between standard and execution times. Furthermore, it determines how badges are collected as well as the use of the rest of the game elements. However, it is interesting enough that leaderboards are not used on a daily basis, in order to suppress social pressure and demotivation due to competition and ranking positions. Performance graphs and avatars are adapted to players' preferences and progress. All game elements are used to satisfy workers' innate psychological needs for autonomy, competence, and social relatedness, while also providing them with direct, informative, and goal-oriented feedback.

Nevertheless, despite its merits, this study is subject to limitations. First, the gamification framework, especially the point system, lacks practical application and the data used are arbitrary, even though some points reflect reality. Hence, most results, apart from the point system, are based on empirical studies, rather than a real case study or experiment. Moreover, the development of the AR module is a prerequisite for the gamification one, in order to implement the system properly. However, it is crucial to address the novelty of both technologies, the lack of familiarization, and their impact on the respective acceptance. The authors also acknowledge the high costs that come with the proposal, indicating that this framework may not be applicable to smaller warehouses with lower budgets and fewer resources.

Nevertheless, the proposed system can be further improved, by adding more game elements, such as challenges and meaningful stories, altering the use of the current ones as well, or even make different reductive assumptions. The authors' future objective is to develop the necessary APIs for both modules and proceed to a practical application of the gamification framework in a real order picking setting, ensuring game tolerance with time and fairness for all players. In conclusion, this proposal could be a trigger and serve as a strong basis for warehouses to implement gamification techniques, expecting encouraging results.

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