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LEAN CONSTRUCTION ENTERPRISE MANAGEMENT: THE VALUE AND POTENTIAL OF THE MERIT GAME SIMULATION

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ABSTRACT

A Lean Enterprise Construction-aligned learning game is an opportunity to meet the industry's needs and wants. Competitive Simulation can offer such an alignment by using an online system as a medium to instruct. Learning three critical components: vocabulary, concepts, and processes, as well as game-based learning, allows students to acquire knowledge and skills through an interactive and entertaining learning experience to achieve the purpose of real-time teaching. As a result, many educators have adopted gamification in various disciplines in the tertiary sector to enhance learning and teaching. This paper will discuss applying the MERIT game to Lean Construction Learning through a case study within a leading Australian university. The case study incorporates the Merit Game and relevant organisational management content into an undergraduate construction management program. Its focus is Lean Enterprise principles and concepts. Overall, students reported a positive learning experience with higher-order learning outcomes while identifying good practices incorporated into future delivery programs. The case study findings will inform academics and training professionals about the potential of the MERIT game, if tailored, for teaching Lean Construction at the enterprise level.

KEYWORDS

Gamification, Online Simulation, Project Management, Construction Portfolio Management

INTRODUCTION

Introducing Lean Construction (LC) through an online game with peer competition offers a robust approach to educating emerging professionals. Effective learning games motivate students to apply principles that expose them to the content and enhance their situational thinking. The adoption of gamification in higher education has become commonplace, with an increasing number of educators embracing it across various subjects to enhance student engagement and performance (Gómez-Carrasco et al., 2019; Swacha, 2021). Nevertheless, the incorporation of gamification into Lean Construction education and its community remains a developing area.

One of the seminal works in the Lean movement was Womack and Jones' (1996) book, "*Lean Thinking: Banish waste and create wealth in your corporation*." This publication signalled the critical nature of enterprises in minimising waste and producing higher value.

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Lean Construction Enterprise (LCE) dynamics are primary lessons in the MERIT Game experience. According to Tsigskas (2022), knowledge capture about LCE should be:

- Production and administration processes driven solely by complementarity of activities to increase profit.
- Flow of work, material, information, and cash through digitisation.
- Adaptation strategies and methods to changing market conditions.

These three understandings provide the learner with a starting point to build upon. They can progress their mastery to more nuanced and powerful ideas that scaffold from these foundations.

MERIT GAME AND EQUIPPING STUDENTS WITH PRACTICAL SKILLS

There is a small but significant threat to tertiary education if relevant skills are not reliably captured by their graduates. Business Insider (2024) reports that 37% made progress in skills-based hiring, including Walmart, Apple, and Target, and 45%, took college requirements out of job postings such as Bank of America, Amazon, and Lockheed Martin. Still, they failed to institute actual changes in their formal process and hiring documentation. However, it may be an emerging signal from the market about the value and hunger for relevant skills.

Recognising the importance of equipping students with practical skills, one construction management program (WSU 2020) has integrated the MERIT game into its curriculum. This game-based approach aligns with the evolving needs of the construction industry and offers students hands-on experience in managing project portfolios. By bridging the gap between theoretical knowledge and practical application, the program aims to prepare students for the dynamic challenges of the construction sector. Additionally, the MERIT game addresses challenges in direct labour management. This feature resonates with the prevailing market reality that approximately ¾ of construction firms are characterized as non-subcontract yet labour-intensive entities (Stevens and Smolders 2023a).

PROJECT PORTFOLIO DYNAMICS

Modern construction projects' larger size and increased complexity have catalysed the development of improved leadership and management training methods for leaders and managers – matriculating or working (Ahmed et al. 2014). Educational games such as MERIT simulate the intricacies and interdependencies in real-world project management, making it an excellent platform for conveying complex concepts and promoting deeper understanding. The MERIT game's foundational work is manifested in Modern Construction Management (Harris et al., 2021) and its seven editions, first published in 1983. The book focused on construction organisational leadership and the many simultaneous projects that are ongoing at any one time. The MERIT game was published, and its first competition was held in 1989.

Constructing a project is a linear one-off process in which every mistake affects two or more tasks downstream – early mistakes are especially pernicious. A contractor's business involves managing several critical paths and their myriad of tasks to produce cash flow, profit and a good reputation. Risk is well-managed when a company is sensitive to incorrect or tardy task executions (Stevens and Smolders 2023)

Building upon the educational benefits of gamification, particularly demonstrated through the MERIT game, it is essential to explore the broader dynamics of project management, specifically focusing on Project Portfolio Management (PPM). By integrating game-based learning experiences like the MERIT game with discussions on PPM, students can understand the complexities and challenges involved in managing multiple projects within an organisational context.

The MERIT game effectively simulates the challenges and opportunities inherent in PPM, a strategic framework integral to effective project management that aligns multiple projects

with an organisation's broader strategic objectives (Project Management Institute, 2000). Effective PPM needs a structured process, including risk assessment, estimated profitability and an overall strategic fit to the corporate goals (Bilgin et al., 2023). PPM focuses on dovetailing projects into a time and resource demand framework unique to the constructor and requires a vastly different approach than project management (Oltman, 2008).

As an example, the staffing of projects is not primarily for the site manager to decide but typically a home office executive who balances all the current project's demands. The Lean project production practice of Percent Plan Complete, as described by Stevens (2015), may not align with realism. For educators, a solid grasp of PPM is essential for students in the construction industry, where managing multiple interrelated projects as a Project Manager or as a Managing Director is a certainty.

PPM's strength lies in its ability to handle the uncertainties and complexities often encountered in projects. It offers a flexible approach that can adapt to changes and unforeseen challenges, ensuring project success (Cooper et al., 2000). One significant advantage of PPM is its approach to understanding and managing the interconnections between different projects. Managing these connections in environments where projects are closely linked regarding resources and goals is vital for resource efficiency, avoiding delays and cost overruns (Engwall & Jerbrant, 2003).

Moreover, PPM significantly contributes to enhancing project success rates. Effective PPM involves regular portfolio reviews, strict schedule adherence, and a readiness to allocate additional resources when necessary, resulting in more successful project outcomes (Unger et al., 2012). Furthermore, effective PPM helps mitigate counterproductive practices such as overburdening teams and thinly stretching financial resources across numerous projects, which can lead to poor quality and project failure. Instead, PPM advocates for a balanced distribution of resources, ensuring that each project receives the necessary support to thrive (Levine, 2005). Additionally, PPM aligns projects with the organisation's long-term goals. Organisations can direct their efforts towards achieving broader objectives by selecting and prioritising projects based on their strategic value (Archer & Ghasemzadeh, 1999). Thus, PPM offers numerous advantages for organisations seeking to optimise project outcomes and align them with overall strategic goals. Its application provides a comprehensive framework for addressing uncertainties, managing interdependencies, improving success rates, ensuring balanced resource allocation, and aligning projects with strategic objectives.

This paper utilises the Introduction, Methods, Results, and Discussion (IMRAD) framework to examine opportunities and assert reasoned directions for the effective use of gamification in construction management teaching and learning.

METHOD

This research employed a case study approach, utilising the MERIT Game online simulation within an elective subject, Construction Business Management, at Western Sydney University (WSU). The researchers utilised this simulation to collect and analyse data, including direct observations. The study collected data from the most recent two years of weekly competition results, as well as post-competition student reflection papers.

THE MERIT GAME STRUCTURE AND PROCESS

The MERIT game places each student as a board member for a publicly held and prime construction contractor employing direct labour. The simulation encompasses six specialised management areas.: a) Financial b) Overhead c) Estimating d) Bidding e) Personnel and f) Construction. Typically, teams are comprised of 4 students and self-regulate.

Three- to six-person groups are created at the start of the subject – some self-form, while unattached students are assigned. It is recommended that each student be assigned responsibility

for two of the six areas – finance, overhead, estimating, bidding, personnel, and construction. This is an intended overlap to prompt members' decision-making and interaction. Each member is encouraged to add their perspectives in the decision-making process for unassigned areas.

From the first to the fourth week of the semester, the instructor narrates the purpose (the "why"), vocabulary, concepts, and preferred process for successfully engaging the game. The teaching intent is to encourage new approaches or, at minimum, iterative improvements to engage the game successfully.

A 20-question assessment is given to individual students. Afterwards, groups are expected to enter their decisions in a 2-week trialling period for students to familiarise themselves with the program. Each class period is spent with two to three groups entering their decisions into the program while sharing their screen with all attendees. Subsequently, an 8-period competition follows. Teams who earn at or above 2,000 points receive full marks, and those scoring less are given a prorated score. After the trialling period, another more detailed online quiz is given. It is equal to the first but demands more mastery for a passing mark. This serves indirectly as a self-check for student preparation before the competition starts.

The simulation starts in the fifth period after the previous board exits. This means the flow of work and follow-on outcomes are somewhat uncontrollable for the student groups. Previous decisions affect the current opportunities. This downstream ripple effect is realistic for the industry. For each period, an analysis of the results has to be conducted. This limits planning options and informs the students of the stubborn linkage between earlier decisions, current outcomes, and future possible actions. The previous board effect (and their decisions) shows one dimension of uncontrollable factors present in construction. In this way, projects can be viewed as income-expense flows and critical path management challenges.

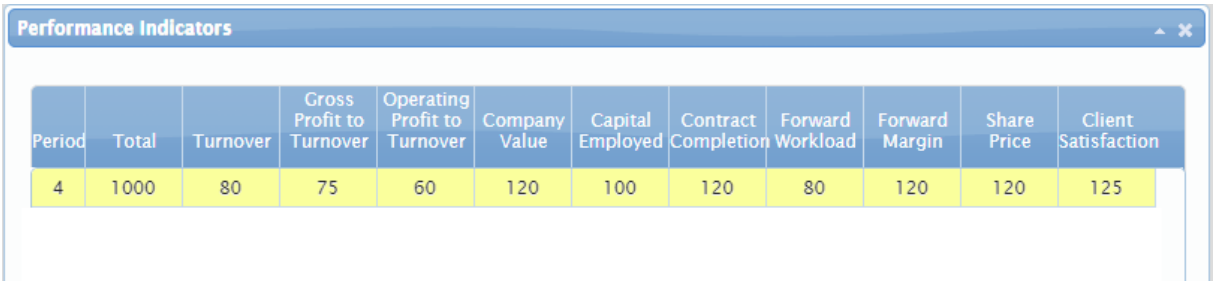
A reflection paper is required from all student groups as their final assessment. Four areas of inquiry are expected to be answered:

1. Individual student's expectations
2. Previous Assessments' Value and Lessons Learnt Individually and as a Team
3. Strategies and Decision-Making in Each Period
4. Reflection and Conclusions
    a) What were the challenges of working individually and as a group?
    b) What skills did you and your group acquire or strengthen?
    c) What were your individual and group lessons learnt
    d) What are your group's suggestions for future participants?

There is an intended overlap of each query's content disclosure. The researchers have found that prompting answers in the template encourages expansive and complete reflection. So, a template is provided so teams will answer the core questions and ponder "what if" and lessons learnt.

THE MERIT GAME SCORING

The MERIT Game total scoring is multifactor. Based on ten metrics, groups decrease or increase their starting 1000 points after weekly decisions. See Figure 1. The emphasis is on a balanced approach to the construction of work. Construction PPM has little room to focus on a single or a few outcomes. In the opinion of the MERIT game creators, this will lead to a deterioration of the firm's viability. Additionally, the weighted approach of the outputs guides the boards of directors to be more sensitive to transcendent results, such as client satisfaction and less so, such as operating to turnover. Of course, financial stresses will show seminal importance as the subject company is restricted in tendering and bidding options.



Period	Total	Turnover	Gross Profit to Turnover	Operating Profit to Turnover	Company Value	Capital Employed	Contract Completion	Forward Workload	Forward Margin	Share Price	Client Satisfaction
4	1000	80	75	60	120	100	120	80	120	120	125

Figure 1. Assessment Report of Individual Components Showing the Starting Point Total

Construction contracting involves early collection and confirmation of information for each project built. Excellent pre-project planning is contingent on this (Stevens et al. 2023). Effective PPM requires capturing, analysing, and distilling project and organisational data into actions. There are over three dozen reports to view and digest. See Figure 2.

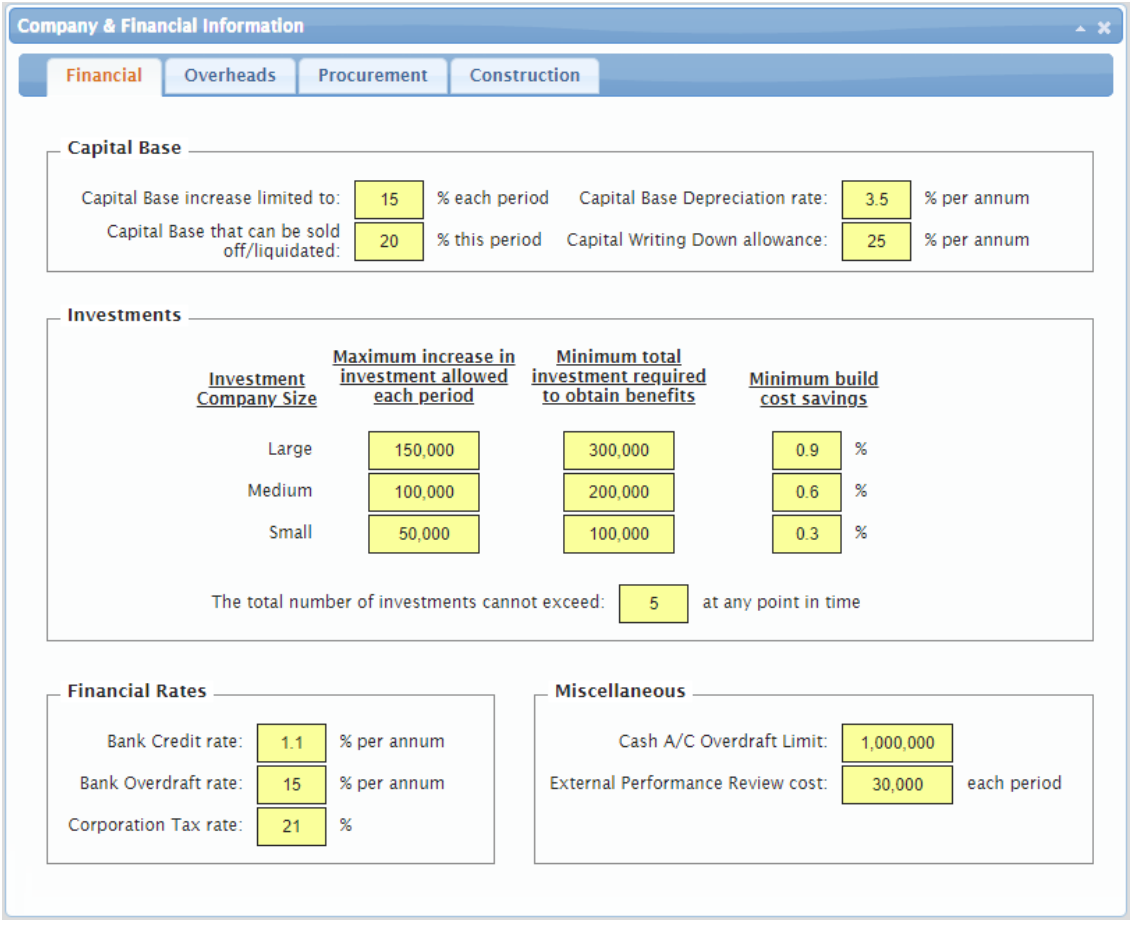


Figure 2. One Example of the More than Three Dozen Reports and Ratio Guidelines

LEAN CONSTRUCTION APPLICATION

At the start of the semester, we propose that students capture key concepts and reorient their thinking by applying Lean Concepts to the dynamics of construction contracting PPM. Indeed, the basics will start the process of rethinking productivity in construction contracting. This change is relatively minor to the subject's content.

1. Lean Thinking versus Muda. One role of Lean leadership is teaching people how to see waste. Lean philosophy makes it a priority for stakeholders to suggest methods to convert waste into value.
    a. Type 1 Muda - Necessary but, non-value-creating practices, such as client meetings (where project results are physically evident and outstanding issues can be documented without interpersonal contact) or multiparty approval (practised in a bureaucracy).
    b. Type 2 Muda - Non-value creating and unnecessary, such as amenities (supports operations and does not directly produce work), and marketing activities (completed work done well is the best sales practice)
2. Value - Value creation can be defined as results sought by clients in which they will pay per an income schedule. Certainly, after several projects, those contractors that have consistently met safety, quality, cost and schedule demands can tender and win at a higher proposed price than the average competitor.
3. The Value Stream - In Value Streaming, many project tasks are interrelated and ordered, and when executed well, they positively affect safety, quality, cost, and schedule. Of course, clients may add environmental, economic, and social metrics to their requirements.
    a. Many steps will be found to create value unambiguously.
    b. Other steps will be found not to create value but are necessary due to current technology and production assets – Type 1 Muda
    c. On an average project, it has been found that several steps create no value and are immediately avoidable – Type 2 Muda

It is critical to explain to students that three tasks are involved in Value Streaming

- Problem-solving Task – taking information and designing an action involving a product.
- Information management Task – collection and confirmation of project facts distilled into planning through detailed scheduling to delivery.
- Transformation Task – product and labour to install the specified item on the job.

Identifying the entire value stream for each action/installation means a team understands and can improve. What is not understood cannot be improved.

4. Flow - Flow must be a priority focus by the team in construction. The demand of resources for the work available is synchronised (Single Piece Flow) Using “chaku chaku” or “load load,” one worker or manager takes a task from the information gathering stage to completion as practicable—the opposite of batch and queue.
5. Pull - a formalised trigger of work ready to install determines the short-term allocation of resources for a specific task – in construction, it may be a building floor or infrastructure area.
6. Perfection - The improvement journey is inefficient and frustrating if you find “just good enough” rather than perfection. The constant striving to reach a process error and defect-free state motivates employees steadily and specifically.

Table 1: Proposed Conversion of the MERIT Game Vocabulary and Concepts to Align with Lean Construction

MERIT Game Concept	Explanation	Lean Construction Concept
Hiring and Layoffs of Managers and Workers Increase Costs.	Forecast resource demand for the current and future demand across the portfolio of projects to increase utilisation and lessen waste and resulting crises. This includes co-locating cells of production. In construction contracting, equipment shops next to tendering and PM departments cause people to communicate face-to-face, which lessens conflict and increases social and business interaction.	"Heijunka" or Levelled Workload
Governing Structure – Executive Structure Allocates Resources Among Projects	This is a critical component of portfolio management, a strategic planning tool that requires executive management to select three to five objectives – all others are deselected (Juran 1995).	"Hoshin Kanri" or Executive Level Resource Allocation
Redundant Systems and Double-Checking Keep Errors Minimised	Mistake-proofing and Trouble-blocking methods limit or eliminate potential rework and crises. (Tommelain 2008). A customised spreadsheet is recommended for students to minimise math and calculator mistakes. See Figure 3.	"Poka-yoke" ("Baka Yoke") or mistake-proofing
Construction Decision-Making	Construction Contractor must set the production rate (cycle time) to exceed customer demand due to the industry's many uncontrollable factors causing unforeseen delays. It is a core principle of LC. Meeting Takt Time assures that the project fulfils all functional requirements within the set time, positively influencing cost and quality. It must be planned and verified by a structured process, managerially driven from the tender stage and pre-mobilization planning to practical completion	"Takt Time" or Customer Required Delivery Time
Supporting Spreadsheet	The pre-programmed spreadsheet represents a simple ITC application to assist teams with rapidly calculating critical numbers. This supplants a hand calculator approach and frees up more time for iterating improvement ideas.	LC's 8th principle, "Use only reliable, thoroughly tested technology that serves your people and process"
13 Class Sessions of Trialling and Competition	The instructor selects two student teams each class session during the last 12 weeks (each team is present watching and listening) Review the previous week's decisions and results Points out key insights and suggests ideas for improvement	Kaizen

At first, students may not appreciate the structure and decision-making process needed to succeed in the MERIT game. The game produces over three dozen metrics that indicate critical strategic and operational direction from the previous period. Many indicate a strengthening, static or weakening company position. Measures such as utilisation percentage, on-site cost per worker, and estimating confidence alert the teams of deficiency or perfect optimisation. This

consistent reality that collecting and confirming a myriad of information items affects the next period's decision-making is a realistic pressure. See Figure 3.

Job #	Estimating Confidence	Current Total Site Cost	Current Per Person Site Cost	Overstaff Limit	Period 4 Labour Needed	Period 5 Labour Needed	Period 6 Labour Needed	Period 7 Labour Needed	Period 8 Labour Needed	Period 9 Labour Needed	Cost Based on Current Performance	Lay Off	Billing Projected	Cash Needed Next Period
3	Extremely High	657,138	10,268	45.00%	64	64					657,138		$3,587,908	$3,493,581
10	Extremely High	74,890	14,978	35.00%	5	9					134,802		$840,835	$456,896
12	Extremely High	175,034	17,503	25.00%	10	15					175,034		$1,590,390	$1,039,471
19	Extremely High	0	#DIV/0!	45.00%	0	42					#DIV/0!		#DIV/0!	$0
20	Extremely High	0	#DIV/0!	45.00%	0	81					#DIV/0!		#DIV/0!	$0

Figure 3. Spreadsheet Critical to Organising Inputs and Calculating Outputs

DISCUSSION

Trends in construction education point to emerging opportunities and threats. Employers appear to be starting to embrace skill-based hiring criteria. Students with general management degrees without an understanding of current issues may be losing their perceived value to contractors. The largest employers from several industries are signalling dissatisfaction with graduates.

PPM is a reality for construction contractors and their managing directors. Teaching this skill will often serve future corporate leaders and their project managers. Since most contractors, including specialist contractors, manage labour directly to complete projects, the scopes they agree on are a fraction of the total project size, so PMs manage multiple jobs.

Construction contracting is a VUCA business, i.e., volatile, uncertain, complex and ambiguous, a phrase and concept created by Bennis and Nanus (1986). There is a critical need to use a proven system to attain alignment of the many contractor functions. Lean Construction has proven to beneficially guide the dozens of decisions that need to be made that affect safety, quality, cost, and schedule. Said differently, there is more certainty and speed when all decisions dovetail efficiently. It is vital since poor decisions negatively impact follow-up tasks.

In construction contracting, factorials show us the complexity dimension from an increased number of projects, i.e., this leads to a disproportionately more significant number of possible combinations and, thus, risk event probabilities. Each project varies under the conditions it is built, such as client expectations, design uniqueness, material required, contract terms, and site conditions; therefore, it contains many new variables. Additionally, multiple projects have different work-in-process percentages, undocumented promises, dozens of interrelated tasks and differing specifications. This PPM challenge is significant. So, comparing two portfolios – a) four projects to b) eight projects, i.e., possible combinations are written as n! so,

a. 4! projects means that there are 24 interconnections, i.e. 1x2x3x4
b. 8! projects translate into 40,320 interconnections, i.e. 1x2x3x4x5x6x7x8

Projects demand shared resources such as craftworkers, project managers, site supervisors, cash, and equipment. However, people are the "wild card" in the construction business. Project managers and site supervisors are unique, and when they interact with others, the predictability of positive results decreases. So, if an executive can keep the variability in people (employees, clients, and stakeholders) less, the probability of risk events manifesting is lower. Contrast this to manufacturing; for example, if a company has produced 100,000 of a product, making one more is less costly and risky than creating the first one. No other industry is exposed to this factorial dynamic. Thus, error rates trend higher than others, meaning mistake-proofing has value in reducing rework and its disproportional cost.

Presently, Information and Communication Technology (ICT) is a default option for universities' education challenges. The MERIT game can be viewed as a mature educational

product. It reflects LC's 8th principle, "Use only reliable, thoroughly tested technology that serves your people and process". It has been on the market for over 30 years and is based on a textbook in its seventh edition. Refreshing its content, structure, and process will extend its useful life. This paper suggests that the Lean Construction approach can be embedded as an electronic game to further construction management education.

For the continued relevance of construction management graduates, their programs should continue to evolve in content and delivery. The MERIT Game reflects the industry's realities, especially those subcontractors comprising ¾ of the industry and main contractors constructing smaller projects.

CONCLUSIONS

The Lean Enterprise approach to construction contracting is efficient for achieving high scores in the MERIT Game, thus a beginning competent understanding of PPM dynamics. Increasing project complexity and size continue to challenge constructors. Lean Construction is a proven answer.

The researchers envision changing labels and instructions for the present MERIT game to become a useful Lean Construction teaching tool for the Community. This would be a second product that the game creators should consider. It would involve less time and expense than a bespoke one. Lean thinking is a mainstream and valuable approach to raising value and eliminating waste.

Based on the researchers' career experience and observations, PPM is not consistently taught in universities' construction management curricula. This is a misalignment with industry realities. Many graduates will become project managers who lead more than one site at a time. A smaller percentage will become construction company owners. PPM mastery is the challenge. There is little reason for educators not to confront this reality. The good news is that a ready application exists to start from. Iterative improvement can be pursued quickly.

"Business as Usual" is not acceptable in construction education, given the significant project complexity and size increases. Educators must match this rising intensity. If not, contractors may be likely to discount the value of graduates and hire more under-21 recruits with good mental, emotional, and spiritual composition and train them in needed skills. Said differently, utilising new ways of educating while covering critical gaps should keep pace with industry demands.

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