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DEVELOPMENT AND TESTING OF A SIMULATION GAME ON WASTE ELIMINATION USING LEAN PRACTICES

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AGENDA

- INTRODUCTION
- GAME DEVELOPMENT
- GAME TESTING
- POST SIMULATION DISCUSSION
- CONCLUSION

INTRODUCTION

- Waste - a pivotal concept
- TFV theory of production – "***elimination of waste and non-value adding (NVA) activities***" for better flow management. Koskela (2000)
- "Lack of understanding knowledge on Lean and Complexity of Lean philosophy and terms" - a potential barrier in the adoption of lean principles. (Demirkesen et al., 2019, pp. 7-8)
- **Simulation Games** i.e., "Learning by Doing" bridges gap between concept and application in a **clear, realistic, and simplified manner**. (Hamzeh et al., 2017; Rybkowski et al., 2018).

INTRODUCTION

- Bhatnagar (2020) compiled 47 lean simulation games and analysed their learning outcomes and lean principles

- "Waste elimination and value maximization" - unexplored theme and not key focus areas of existing lean simulation games like LEAPCON, House of cards, Dot Simulation, Airplane Game (and its variants)

- This paper analyses the ***development and testing of a simulation game*** *to impart knowledge on waste elimination and value maximization using various lean practices* in the construction domain

- Inspired from Airplane game developed by Visionary Products USA, Inc. (2021)

GAME DEVELOPMENT

Main intent of game - To familiarize players with "***Waste elimination and Value maximization"*** concept

Each team to complete "target" of constructing 8 Lego™ houses within 8 minutes to get cash points for defect free houses

Team with highest cashpoints is declared a winner

Played in three rounds with continuous improvement in workflow process

Reduction in wastes by use of 5S, Supermarket, Kanban, Heijunka box, and pull planning.

Prototype Design

- Prototype - typical house design
- Comprises foundation, columns, block walls, roofing and services
- Lego™ blocks - Design units
- Four design codes – D1, D2, D3, D4

- Design code has the same constructability but different colors of all blocks
- All blocks are **green** for D1, **red** for D2, **blue** for D3 and **yellow** for D4.
- Sequence of design code denoted by 4 special symbols – spade, club, diamond, heart

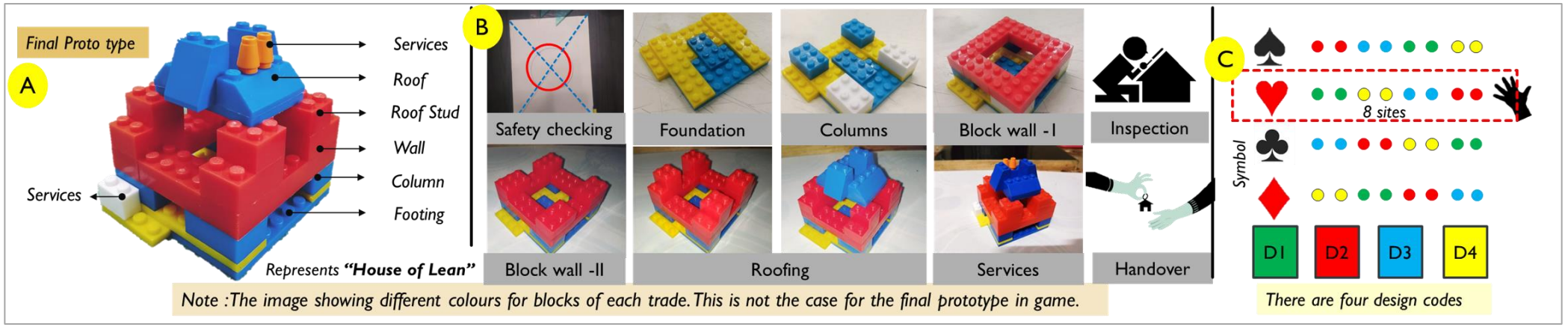


Figure 1. A - Prototype Design , B - Sequence of work, C – Sequence of design codes

Team Composition

Team comprises 8 players

One contractor head, one safety officer and one quality manager

One person each for trades -*foundation laying, column casting, blockwork, roof work and service laying*.

1 assistant and 2 timekeepers per team

The game can be played among 2 - 4 teams with one instructor.

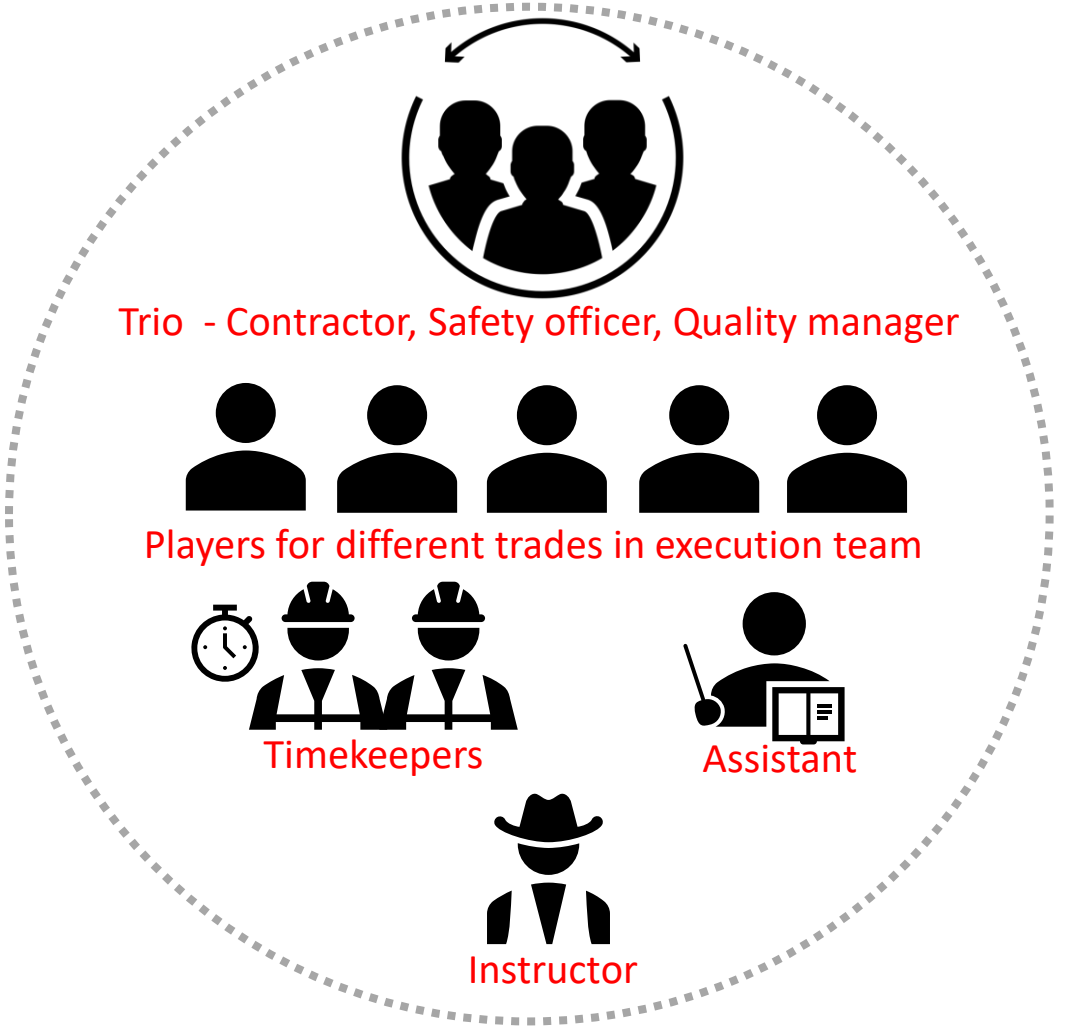


Figure 2. Team composition

Material Required

- Material bowls - 5 per team
- Heijunka boxes - 4 per team
- Templates - Specification card, Format card, Costing template and Design sheet - 3 copies
- Blocks -
  - One is an original block from the Lego™ company
  - Other sourced locally from a local brand called Peco.

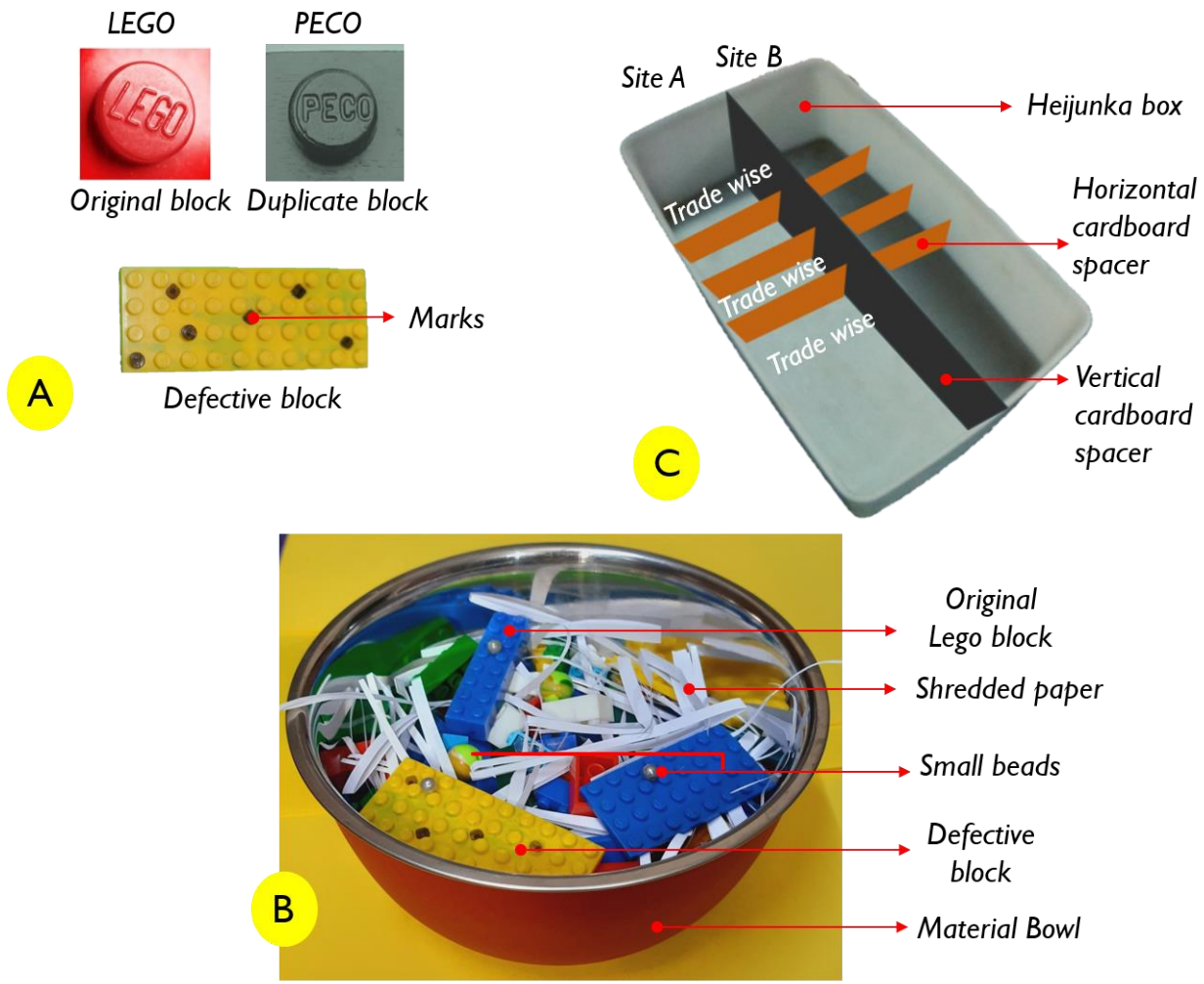
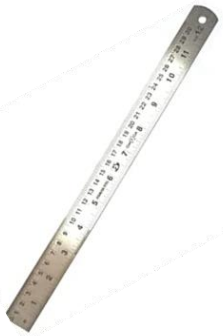


Figure 3. A -Types of blocks, B - Material bowl, C - Heijunka Box

Material Required

A4 coloured sheets



30cm steel ruler

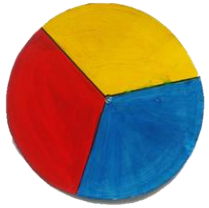
Colourful sticky notes

Sketch pens

Cardboard with circular hole in between of 50mm on a piece of size of A4 sheet.

1 standard 52-card deck

Adhesive tape with dispenser



Circle of 50mm radius with a hole in centre of 3mm

Colourful beads

Glue Stick

Shredded paper

Stopwatch

Figure 4. Additional material required per team

Type of blocks

- One is an original block from the Lego™ company while other is sourced locally from a local brand called “Peco”.
- Lego trademark blocks without any mark are approved in specification sheet
- Few blocks for roofwork are replaced intentionally with duplicate Peco blocks before the start of the game.
- Some blocks are marked with a marker making it a defective piece. This induces defect/rework waste.
- Cashpoints shall only be paid for defect-free sites.

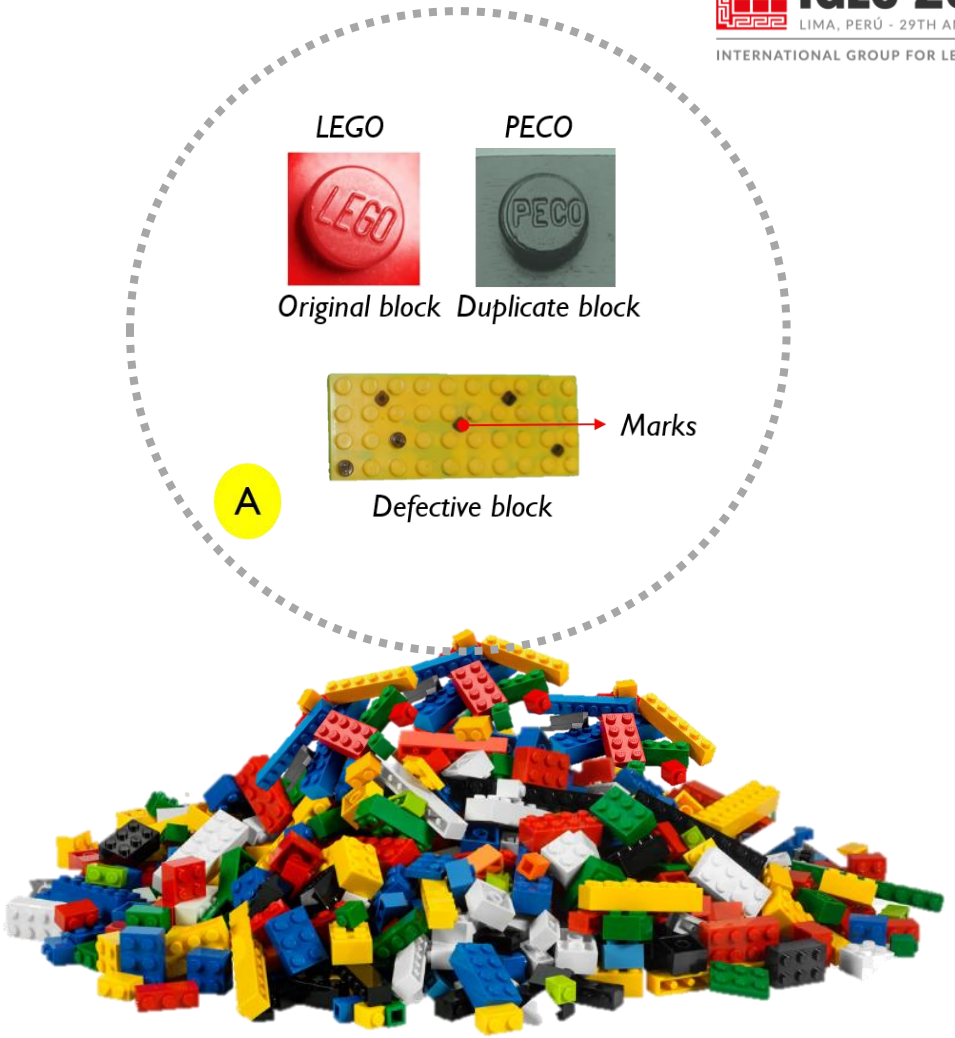


Figure 5. A -Types of blocks

Material bowl design

- Material bowls are not more than 150 mm in diameter
- Depth varies from 50-75 mm.
- Additional materials such as extra Lego blocks of different shapes, sizes, and colours, small beads and shredded paper are also added to the bowl.
- **Bowl design** and **material mix** are intended to introduce difficulty in choosing the right Lego blocks resulting in time and effort wastage
- Allow material to be spread on working station

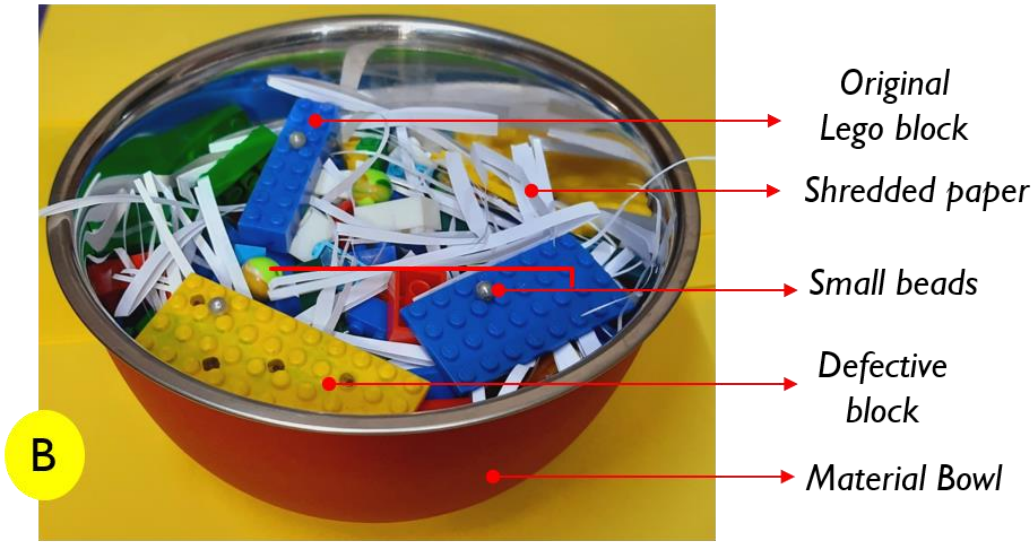


Figure 6. B - Material bowl

Heijunka Box

- Heijunka boxes are used in Round 2 and 3 instead of material bowls.
- Simple rectangular box with an open top and has vertical and horizontal dividers made up of cardboard spacers.
- Horizontal rows - space for each trade
- Vertical columns - sitewise division.
- Used for 5S and resource sharing purposes.
- Enables easy and fast check and choice of Lego blocks.

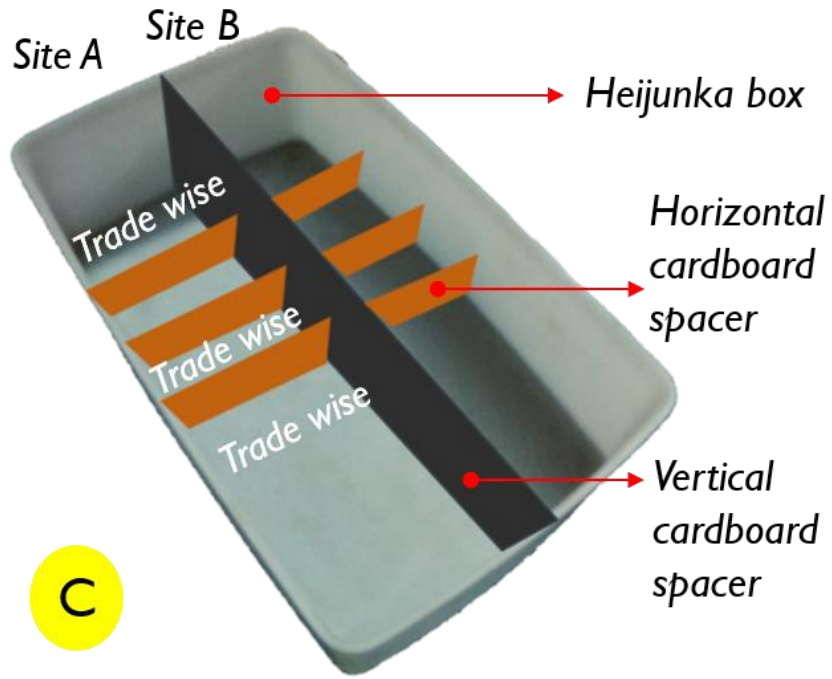


Figure 7. C - Heijunka Box

Templates and cards

Details of various templates and sheets are -

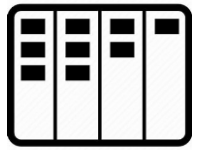
Format card is a template to note the time readings for each player's entry and exit while playing.

The **specification card** defines important instructions such as number of targeted houses and time limit for each round to be followed while playing

The **design sheet** has information on prototype design, design code details and sequence of design code to be followed

Costing template records the cashpoints paid to each trade and profit earned by the team.

Pre-formulated excel template and debriefing questionnaire are also provided.



Sticky notes are used as **cashpoints** in all rounds and as **Kanban cards** in Round 3

Setting Up of Room

- Classroom environment - projector screen and laptop
- Material station and Working station
- Upper half of working station for material movement while lower half for house construction
- Space for 8 sites (A-H) with inter-site 600 mm distance
- Players movement - left to right
- Queuing space in front of material station
- Additional movement space around working station for quality manager

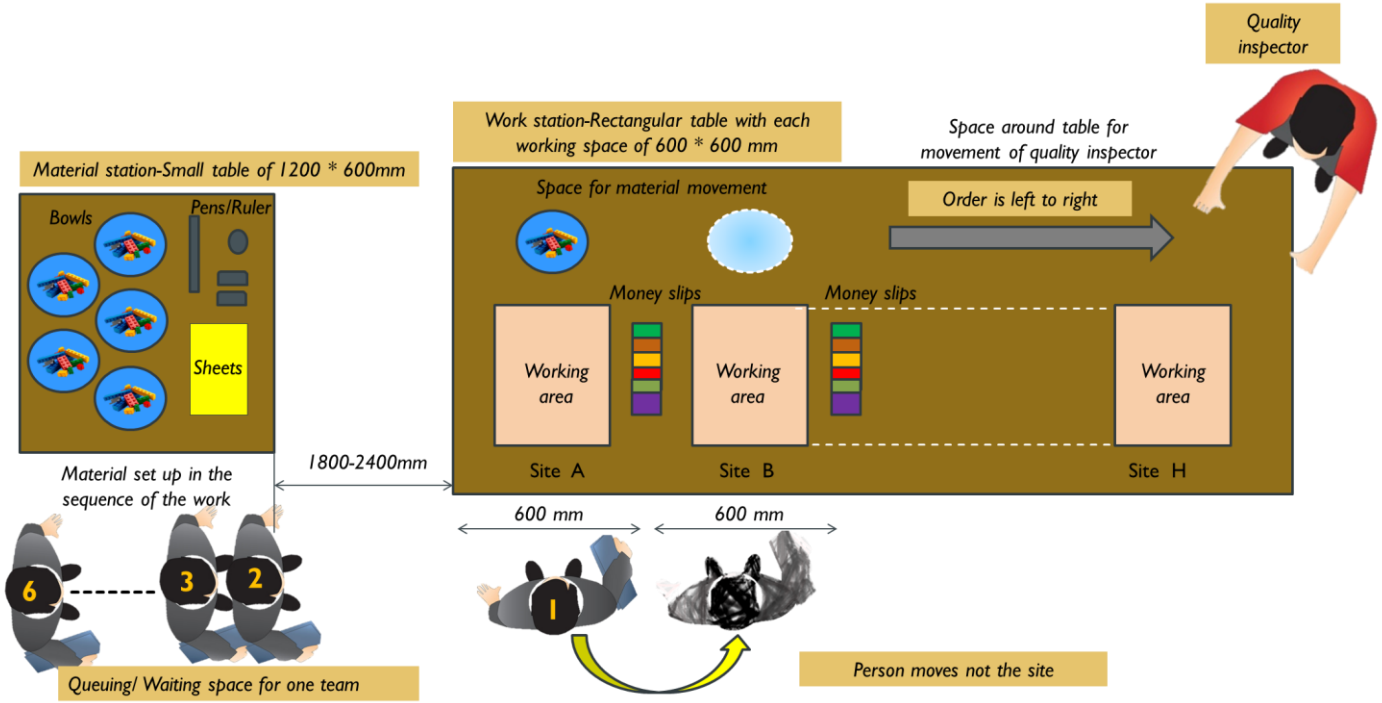
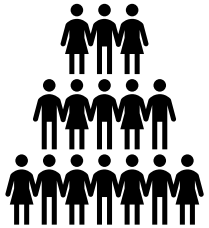


Figure 8. Room arrangement

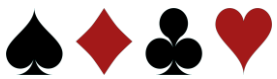
Instructions to play

Formation of team



Assistant distribute templates , design Sheet and material to Contractor Head

Contractor Head chooses one card from the pack of 52 cards.

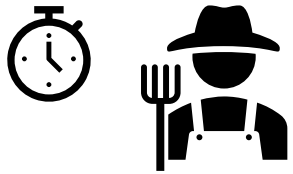


Symbol defines four design codes (D1-D4) sequence

Each contractor head gets 3000 cash points as advance

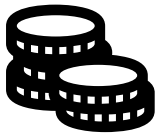
Contractor head returns to its team with target and time limit

Safety officer pastes A4 sheet and drawing a circle at the center for next trades to work



Trades join the required Lego blocks as per design sheet and specification card

Trades paid simultaneously



Quality manager does inspection in end & cashpoints are paid to Contractor for defect-free houses

Timer stopped at 8 minutes, status is recorded

Timekeepers & Assistant record entry and exit of each player , fill cost template and prepare Gantt chart

Debriefing session at the end of each round

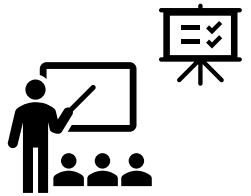


Figure 9. Sequence of play

Round 1

- Represents traditional way of working depicting several "**lean wastes**"
- Batch size – 4 houses
- Working station away from material station
- Safety officer performs non-value-added extra steps
- Use of duplicate and defected blocks in material bowls
- Material bowls move from one site to another

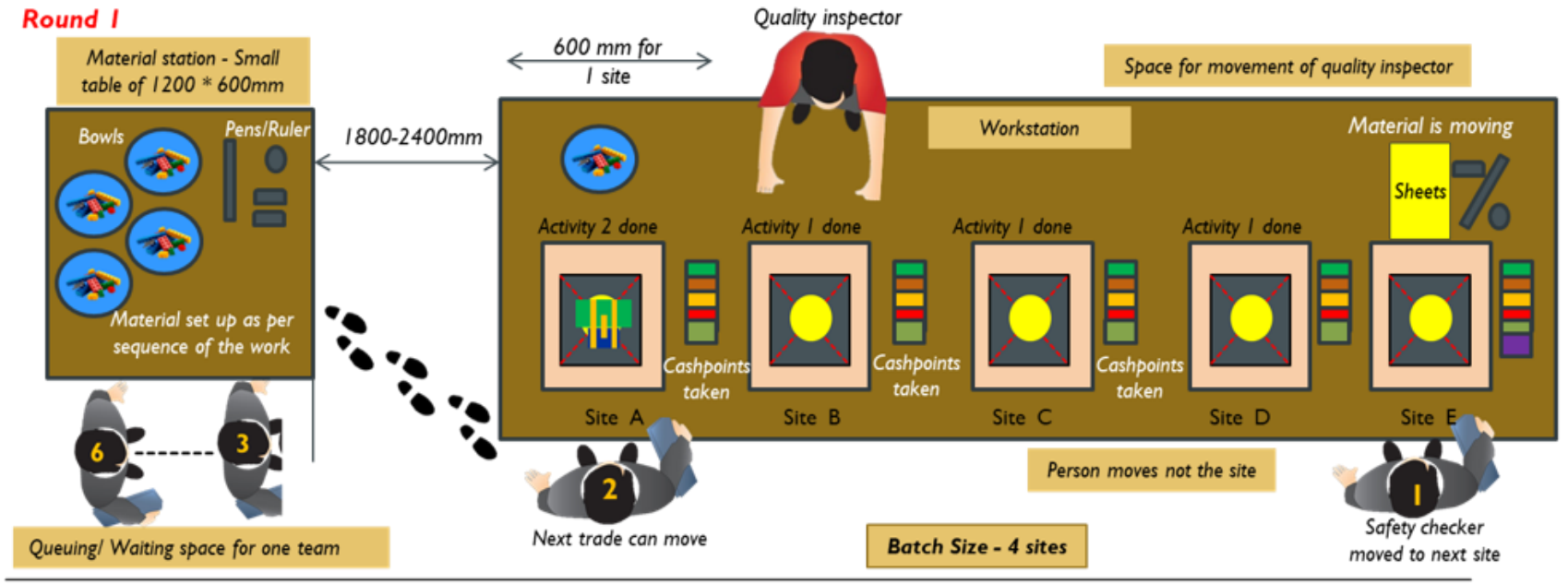


Figure 10. Sequence of work in Round-1

Round 2

- Represents 5S, Supermarket, Heijunka box to improve the workflow and waste elimination
- Batch size - 1 house
- Material station moves closer to working station
- Sorted and well-organized blocks are kept on material station
- Heijunka box kept between two adjacent sites
- Safety officer follows fewer steps to draw the circle

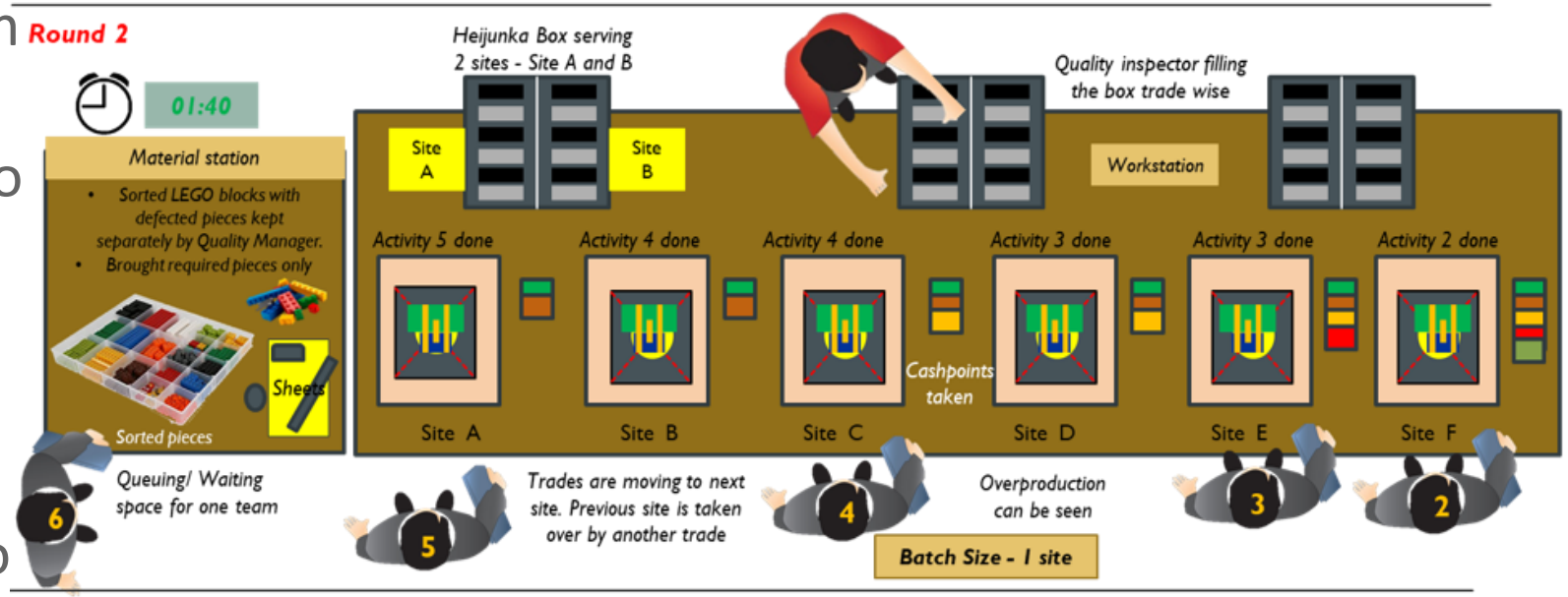


Figure 11. Sequence of work in Round-2

Round 3

- Round 3 shows effects of pull planning, Kanban and workload balancing on the workflow.
- Similar to Round 2
- Players have similar cycle times
- Column casting is combined with foundation laying
- Roof studs is combined with blockwork laying.
- Use of Kanban cards for player movement reduces overproduction

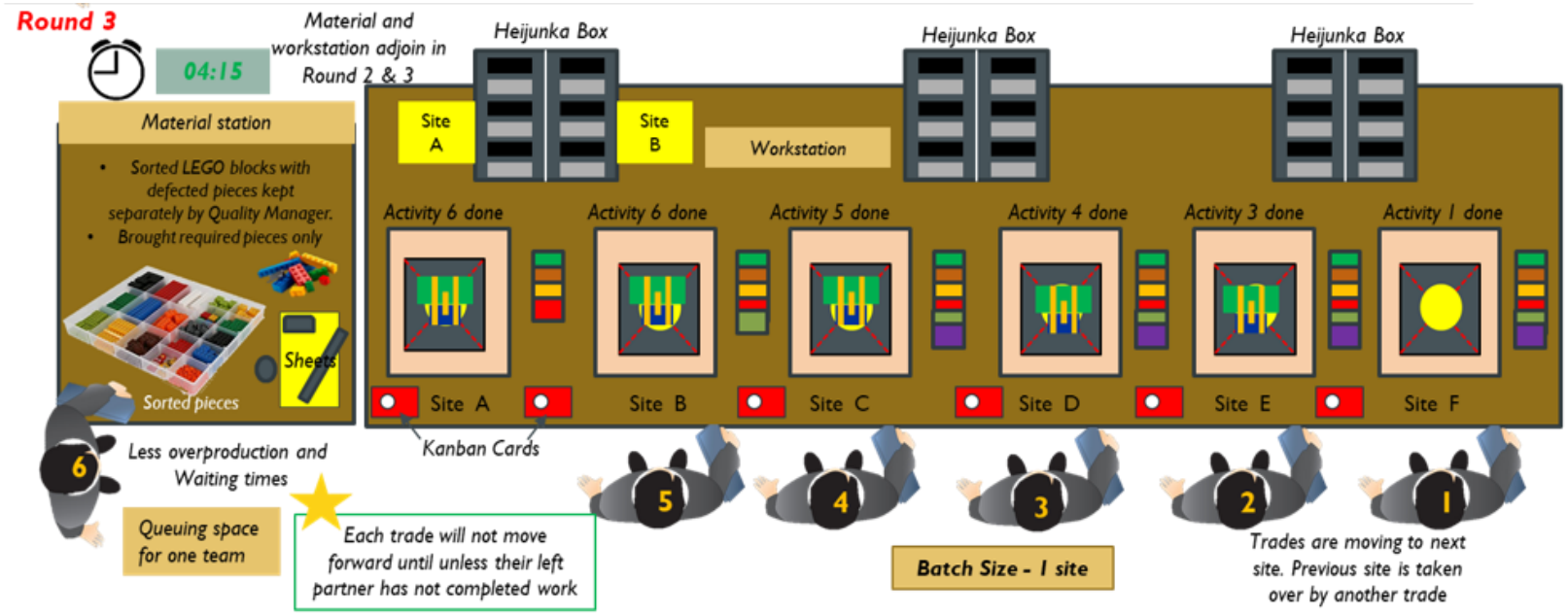


Figure 12. Sequence of work in Round-3

GAME TESTING

- Internal testing group consisted of 10-12 students of Master's program of various disciplines related to built environment.
- Testing was focused on fulfilment of it's learning objectives - ***waste elimination and analysis of Non-Value Adding (NVA) as well as Value-Adding (VA) activities***.
- Time and cost were the drivers
- Cycle times were recorded and fed in pre formulated excel for Gantt chart and cost templates were filled

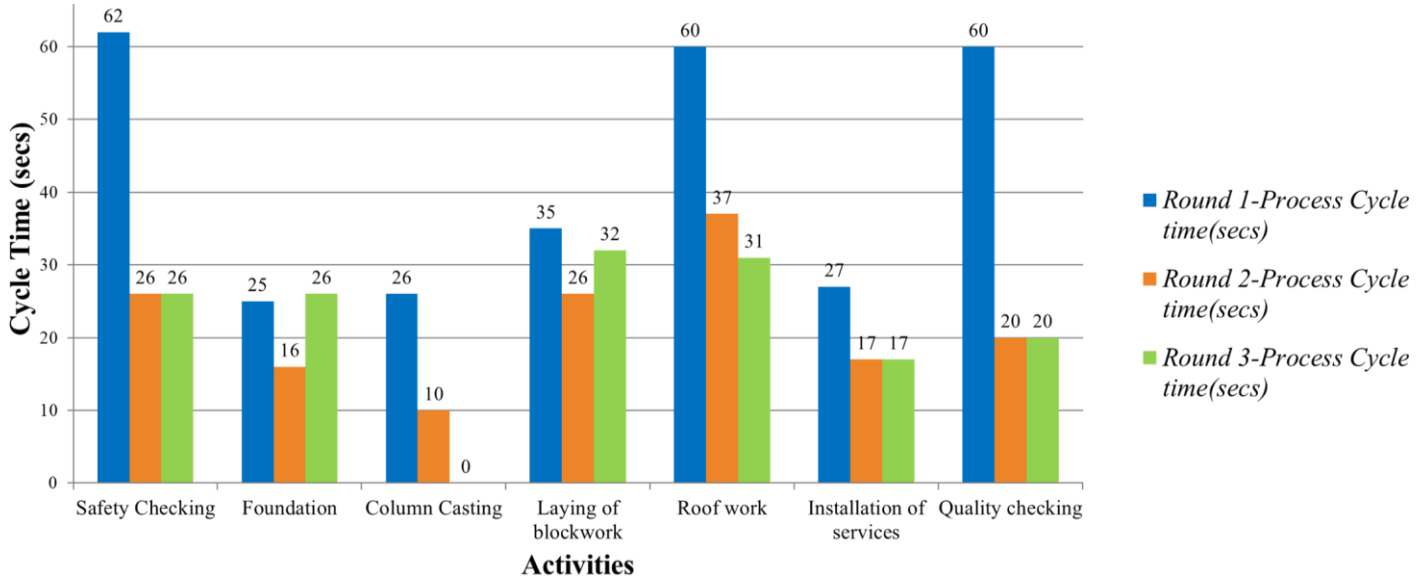


Figure 13. Cycle time comparison of each trade for each round

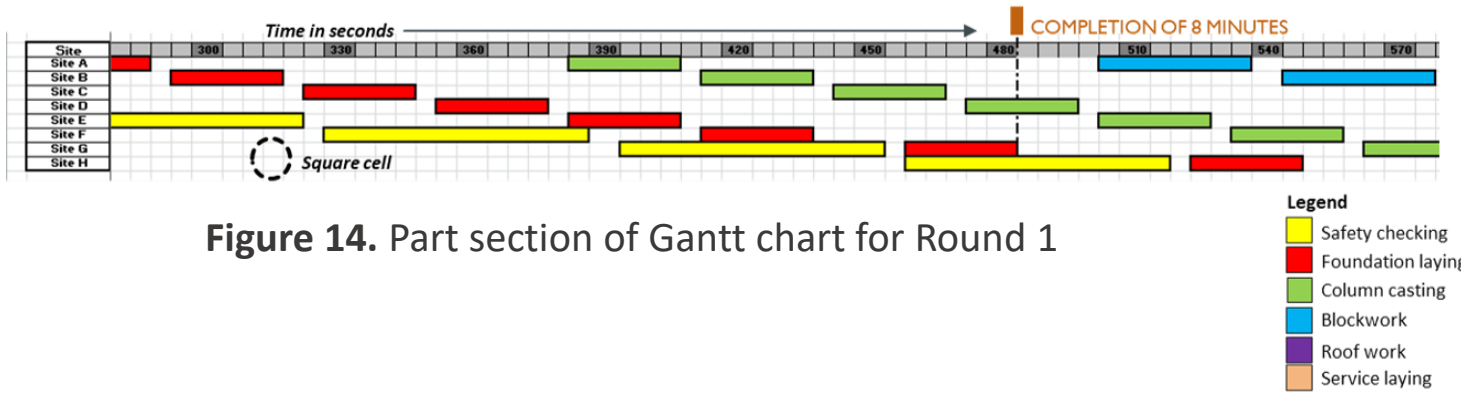


Figure 14. Part section of Gantt chart for Round 1

GAME TESTING

- To test **prototype design** and **game sequence**, numerous runs were played in small sections for analyzing their behavior towards the designed plot to proceed further
- The cycle times and scenarios were recorded with stopwatches and videography respectively

Figure 15. Snapshots from internal testing

Results

Parameters	Round 1	Round 2	Round 3
Profit earned (cashpoints)	**2710**	**3700**	**3940**
Time taken to complete task (min.)	**25**	**8.2**	**7.4**
Cashpoints earned per minute	**108**	**453**	**531**
Cashpoints made in 8 minutes	**864**	**3624**	**4248**

Table 1. Comparative statement of results of each round

- The lead time accounted to more than **300%** improvement and the rate at which the profit was being earned over the rounds increased by **500%** i.e. (4248/864=4.92).
- This means that the same amount of work can be performed in **one third** of the time and **five times** more money can be gained as compared to first round.

POST SIMULATION DISCUSSION

15-minute debriefing session after each round

To summarize their learnings and share their experiences of the game.

Interactions were in the form of group discussion and collecting “plus-delta”

Instructor used a 12-pointer debriefing questionnaire for systematic perspective analysis

Discusses process flow w.r.t. waste and VA/NVA activities with Gantt charts on projector screen

Plus (+) points of feedback - Material bowls design, house prototype and cost variable

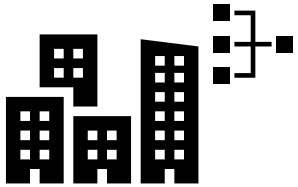
The participants reiterated gradual infiltration of the concepts in the game

Deltas - Space arrangement and use of different colours for different trades in 1 design code

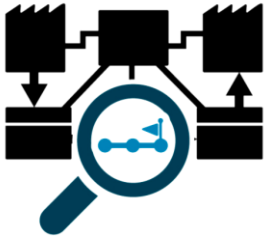
CONCLUSIONS

It was evident that the simulation was effective in providing a first-hand experience of waste elimination and value maximization by the use various lean practices.

Bringing clarity to the to proceed in future systematic identification and elimination of waste in real life construction processes and learn graphical representation of process mapping



Knowledge gain from this game can be enhanced in the form of current and future state maps by integrating of value stream mapping in a simulated form.



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THANK YOU!