Critical Success Factors for Lean Thinking in the Application of Industrialised Building System (IBS)

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Abstract. Productivity in the manufacturing process of building components can be increased by optimising each advantage that is available in each activity. Identification of critical success factors (CSFs) for lean thinking in the Industrialised Building System (IBS) will be able to minimise cost and reduce time needed to complete a project. The focus of lean thinking in construction is on the production process and the client's requirement. In developing countries such as Malaysia, the integration of lean thinking in IBS applications is still low and there is a shortage of comprehensive strategies to integrate lean thinking. As key stakeholders, feedback from contractors, manufacturers, developers and the local authority will be able to help the identification of CSFs in integrating lean thinking in IBS applications. The data was collected through a questionnaire survey and analysed quantitatively. There are 31 CSFs for lean thinking in IBS which have been identified in this study. A conceptual model was developed to assist researchers in investigating the influences of CSFs for lean thinking in IBS applications. This study will assist construction players to improvise their manufacturing process in the implementation of IBS to eliminate unnecessary activities and focus instead on significant processes without generating physical and non-physical waste.

1. Introduction

Lean thinking focuses on people and the processes involved in the manufacturing process [1]. Previous research has shown that lean thinking can improve productivity in the manufacturing process. The integration of lean thinking in the Industrialised Building System (IBS) may increase the benefits of offsite construction in Malaysia. The Transformation Programme, which was introduced to the Malaysian construction industry, urged construction players to adopt innovative construction methods and appropriate management systems to spur sustainable development [2,3]. The implementation of lean thinking in the construction industry can save time by eliminating unnecessary processes through effective management in a construction project [4]. Lean thinking can increase the profits of contractors and manufacturers by easing the process for all activities involved and eliminating waste such as re-handling and repetitive work [5]. This approach has the potential to make projects more

systematic, organised and effective. Each process in the IBS implementation will be examined to determine its necessity and how it can be optimised to provide full benefits to the construction stakeholders.

Previous studies have found that the implementation of the lean thinking concept in the construction industry can minimise the waste of materials, time and effort and maximise value at the same time [6]. This includes transforming waste into resources through the process of recycling. The lean thinking approach is different from normal practices within the construction industry and is generally preferable in short but complex projects. Lean thinking consists of five principals which are (1) specifying value from the customer's perspective, (2) mapping the value stream, (3) creating the value creating process flow, (4) implementing the pull system and (5) striving for perfection. The identification of non-value added activities and creating conversion activities which are more competent are the core principles of the lean thinking concept [7].

2. Research Methodology

Questionnaire surveys were mainly used to collect data in this study. The questionnaire items were developed based on the available literature and were later distributed to the construction stakeholders in Peninsular Malaysia. The aim of this study is to investigate the critical success factors for integrating lean thinking in an IBS. The targeted respondents included clients/developers, contractors, the local authorities and IBS manufacturers. A total of 250 questionnaires were distributed to the targeted respondents. However, only 111 questionnaires were completed and returned. Figure 1 shows the breakdown of the 111 respondents into four organisation types in IBS construction. The largest proportion of respondents consisted of contractors (73%), followed by the local authorities (14%), manufacturers (10%) and clients/developers (3%).

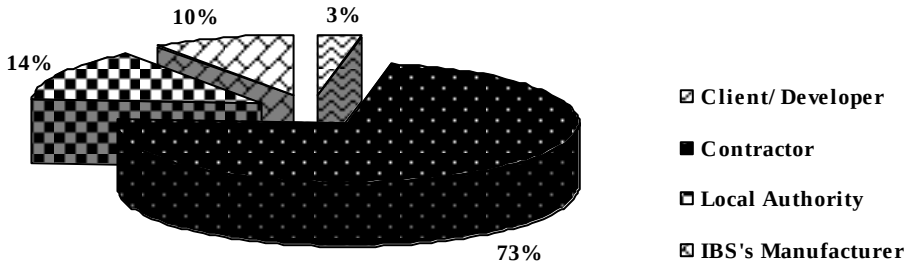

Figure 1. Respondents' organisation

3. Results

By using the IBM SPSS Statistic 22 software, Cronbach's α was calculated to test the internal consistency of the factors. The value of the Cronbach's α is normally between 0 and 1. The Cronbach's α for this study was 0.931 which is a value greater than 0.7 that represents a strong internal consistency of the scale used in the study. The ranking of the success factors of lean thinking in IBS was carried out based on their mean values. The cut off mean at 4.00 was used in selecting the critical success factors. Out of the 59 factors that were identified in the literature review, only 56 were rated by the respondents as significant (mean ≥ 4.00). The standard deviations must be below 1 to indicate the data accuracy of this study.

Table 1. The Critical Success Factors (CSF's) of Lean Thinking in IBS

Critical Factors	Mean	SD	Rank	*t*-value
Leadership	4.64	0.482	1	6.983[a]
Collaboration of organisation	4.53	0.519	2	4.293[a]
Financial funding	4.51	0.520	3	3.922[a]
Readiness of organisation	4.51	0.537	4	3.796[a]
Time management	4.50	0.502	5	3.681[a]
Customer focus	4.49	0.520	6	3.374[a]
Teamwork	4.49	0.554	7	3.168[a]
Barriers in lean thinking implementation	4.49	0.601	8	2.919[a]
Trust among participants	4.48	0.520	9	3.193[a]
Better coordination	4.48	0.537	10	3.091[a]
Effective information transfer	4.47	0.519	11	3.013[a]
Appropriate tools	4.47	0.536	12	2.917[a]
Effective communication	4.47	0.553	13	2.829[a]
Employees' mindset	4.46	0.518	14	2.834[a]
Organisational culture change	4.46	0.569	15	2.584[a]
Ability to compromise	4.44	0.499	16	2.565[a]
Effective planning	4.44	0.534	17	2.396[a]
Financial capabilities	4.44	0.534	18	2.396[a]
On-the-spot decision	4.44	0.551	19	2.323[a]
Adaptability	4.44	0.551	20	2.323[a]
Clear direction and motivation	4.44	0.598	21	2.139[a]
Education	4.43	0.498	22	2.380[a]
Skills and expertise	4.43	0.516	23	2.297[a]
Optimising material used	4.42	0.514	24	2.119[a]
Root cause corrective measure	4.42	0.532	25	2.049[a]
Information exchange	4.42	0.532	26	2.049[a]
Continuous improvement	4.42	0.532	27	2.049[a]
Efficient logistics	4.41	0.513	28	1.939[a]
Operational improvement	4.41	0.547	29	1.818[a]
Operate in diverse environment	4.41	0.547	30	1.818[a]
Top management commitment	4.41	0.562	31	1.601
Lean management system	4.41	0.562	32	1.601
Stability contract	4.41	0.579	33	1.717[a]
Modify environment	4.41	0.610	34	1.631
Lean knowledge	4.41	0.610	35	1.631
Product development	4.40	0.544	36	1.479
Commitment reliability	4.40	0.561	37	1.436
Lean community	4.40	0.622	38	1.294
Self interest	4.39	0.559	39	1.271
Documentation	4.38	0.523	40	1.176
Production planning	4.38	0.557	41	1.105
Cost management	4.38	0.557	42	1.105
Application of lean house	4.38	0.604	43	1.019
Customer focus	4.37	0.521	44	0.998
Transportation	4.37	0.555	45	0.938
Employee involvement	4.37	0.571	46	0.911
Effective management practice	4.36	0.519	47	0.820
Learn from failure	4.36	0.519	48	0.820
Employee behaviour	4.36	0.553	49	0.770

[a] Critical factors with t-value > 1.6588; Kendall's coefficient of concordance = 0.017, Mean score: very insignificant – 1 and very significant – 5.

Kendall's coefficient of concordance test was calculated to determine the coefficient value of concordance of the respondents' ratings for the significance level of 56 factors. This is done to investigate whether there is any association in the respondents' opinions on the criticality of the factors at a 95% confidence level. If the coefficient value of concordance W is close to 1, it indicates that the respondents had similar ways of determining the critical success factors. Meanwhile, if the coefficient value of concordance W is close to 0, it shows that the respondents had diverse ways of viewing the significance levels of the factors. The coefficient value obtained for this study was 0.017 which indicated that the respondents have a diverse way of viewing the significant level of the factors.

Table 2. Kruskall-Wallis statistics for 31 critical factors of lean thinking in IBS

Critical Factors	Mean Rank				Chi square (χ^2)	*p*-value
	G1	G2	G3	G4		
Leadership	45.00	52.05	46.32	20.00	2.515	0.473 [a]
Collaboration of organisation	23.50	52.35	47.18	23.50	4.243	0.236 [a]
Financial funding	50.25	53.74	38.53	25.50	6.546	0.088 [a]
Readiness of organisation	24.00	53.19	44.84	1.00	7.950	0.047[b]
Time management	25.50	52.42	46.55	25.50	3.896	0.273 [a]
Customer focus	27.00	53.02	45.24	1.00	7.184	0.066 [a]
Teamwork	49.00	51.85	47.71	1.50	4.227	0.238 [a]
Barriers in lean thinking implementation	24.00	55.41	35.71	1.50	15.505	0.001 [b]
Trust among participants	51.00	52.28	44.42	26.00	2.457	0.483 [a]
Better coordination	51.00	52.92	41.79	26.00	3.962	0.266 [a]
Effective information transfer	28.50	52.62	46.74	1.00	6.382	0.094 [a]
Appropriate tools	25.50	52.42	46.55	25.50	3.896	0.273 [a]
Effective communication	51.25	54.10	36.92	26.50	7.983	0.046 [b]
Employees' mindset	52.25	51.62	48.34	1.00	4.154	0.245 [a]
Organisational culture change	27.50	52.59	45.55	27.50	3.719	0.293 [a]
Ability to compromise	27.50	53.78	40.66	27.50	6.804	0.078 [a]
Effective planning	29.00	49.94	57.66	1.00	6.940	0.074 [a]
Financial capabilities	53.00	51.74	47.71	1.50	4.181	0.243 [a]
On-the-spot decision	51.50	52.13	46.29	1.50	4.578	0.205 [a]
Adaptability	28.50	51.98	49.34	1.00	5.715	0.126 [a]
Clear direction and motivation	49.00	52.47	43.92	24.50	2.834	0.418 [a]
Education	53.50	52.86	41.66	28.50	3.892	0.273 [a]
Skills and expertise	52.75	50.85	50.03	28.00	0.835	0.841 [a]
Optimising material used	53.75	52.48	43.16	29.00	2.879	0.411 [a]
Root cause corrective measure	28.50	52.90	44.13	28.50	4.223	0.238 [a]
Information exchange	29.50	50.14	55.29	29.50	2.775	0.428 [a]
Continuous improvement	30.00	52.62	45.05	30.00	3.424	0.331 [a]
Efficient logistics	28.50	52.22	46.92	28.50	3.095	0.377 [a]
Operational improvement	52.50	51.22	48.55	27.50	1.035	0.793 [a]
Operate in diverse environment	51.50	53.36	39.89	27.00	5.171	0.160 [a]
Stability of contract	50.75	52.02	46.84	1.00	4.525	0.210 [a]

G1-client/developer; G2- contractor; G3- local authority; G4- manufacturer;
[a] At 0.05 level, the *p*-value is significant
[b] The most critical factor ranked by the organisation group.

A t-test was applied to all 56 factors with the mean values larger than the cut-off value to identify the most critical factor [8]. The critical t-value 1.6588 was applied in this study. The 31 critical factors which remained were 'leadership', 'collaboration of organisation', 'financial funding', 'readiness of organisation', 'time management', 'customer focus', 'teamwork', 'barriers in lean thinking implementation',' trust among participants', 'better coordination', 'effective information transfer', 'appropriate tools', 'effective communication', 'employees' mindset', 'organisational culture change', 'ability to compromise', 'effective planning', 'financial capabilities', 'on-the-spot decision',

'adaptability', 'clear direction and motivation', 'education', 'skills and expertise', 'optimising material used', 'root cause corrective measure', 'information exchange', 'continuous improvement', 'efficient logistics', 'operational improvement', 'operate in diverse environment' and 'stability contract'.

The Kruskall-Wallis test was applied to investigate the significant level of critical success factors for different types of organisations [9]. The Kruskall-Wallis was interpreted as a chi-square (χ^2) in this test to characterise the ratings. Results obtained from this test showed that there is a difference in opinion among respondents based on their nature of work in terms of 'barriers in lean thinking implementation', 'readiness of construction organisation' and 'effective communication' in ensuring the successful adoption of lean thinking in IBS applications.

The Mann-Whitney test was conducted to identify the differences in opinion pertaining to the significance of the factors among several independent groups. In this study, the Mann-Whitney test was carried out to identify critical factors that have any significant difference between the four organisation types. The results show that the contractors, local authorities and manufacturers have a different view on level of significance of 'barriers in lean thinking implementation'. Meanwhile, in terms of 'readiness of construction organisation', contractors and manufacturers possess different views on this matter. Contractors and local authorities also have differing views in terms of 'effective communication'.

Table 3. Mann-Whitney probability value on critical factors of lean thinking in IBS

Group	*p*-value		
	Barriers in lean thinking implementation	Readiness of construction organisation	Effective communication
G1/G2	0.066	0.098	0.872
G1/G3	0.544	0.255	0.372
G1/G4	0.157	0.157	0.48
G2/G3	0.002 [a]	0.187	0.008[a]
G2/G4	0.041 [a]	0.046[a]	0.276
G3/G4	0.064	0.061	0.617

G1-client/developer; G2- contractor; G3- local authority; G4- manufacturer;
[a] At 0.05 level, the *p*-value is significant.

4. Discussion

Currently, the use of lean thinking for improving productivity within the construction industry has received positive feedback from stakeholders in the construction industry. This study observed that the implementation of lean thinking has grown from an early stage in the 2013 [10] to an intermediate stage in 2017. In this study, the categorisation of the critical factors was based on the five principles in lean thinking, namely 1) specify value, 2) map the value stream, 3) establish the value creating process flow, 4) implement the pull system and 5) strive for perfection. Through a systematic approach to define CSFs in lean thinking integration for IBS applications, three groups have been identified, namely 1) management support, 2) process-centered management and 3) training and education. A conceptual model was developed as a guide for construction players to embed the critical success factors of lean thinking in IBS as shown in Figure 2.

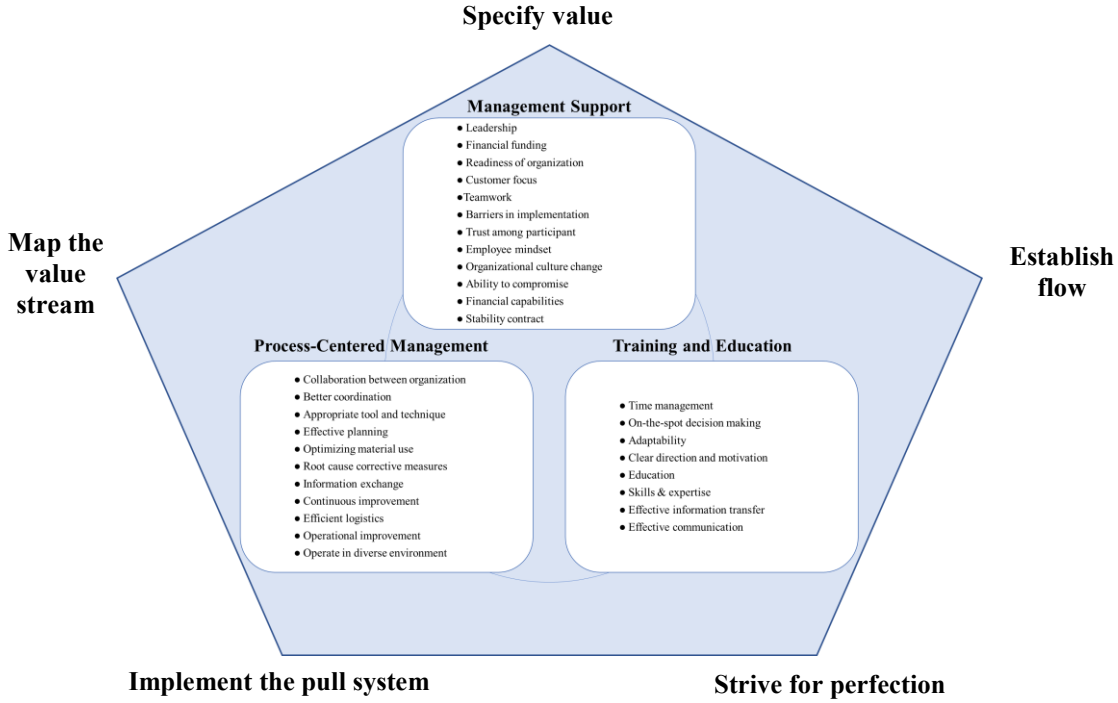

Figure 2. Conceptual model for critical success factors of lean thinking in IBS

4.1. Management support

Changes can be made easily with support from the top management in an organisation. Good leadership will be able to promote the integration of lean thinking in the production of building components [11]. The findings show that with the aid of leadership, effective management of information flow in the production process can be achieved. Leaders can also play the role of an employee who is able to wield influence at whatever level of seniority and responsibility [12]. Having a responsible leader alone in an organisation is incomplete without teamwork among the employees. Teamwork, along with commitment are vital to ensure that employees work together in a coordinated and mutually supportive way. The presence of trust and appropriate tools will keep a team better aligned by developing a charter with production core values which result in quicker decision making that may increase productivity [13]. Based on the analysis, the contractors and manufacturers appeared to have different opinions. Both organisations may have different views due to their differing roles and nature of work. The manufacturers' workplace culture often involves offsite prefabrication while the contractors' workplace culture often involves on-site activities. Several issues associated with contractors and the IBS were highlighted by [14] which included poor knowledge and the lack of familiarity with IBS concepts. The readiness to implement lean thinking in an organisation can be measured when all parties have the ability to compromise by critically leaving behind the "circle of blame" culture where everyone chooses to be indifferent towards any continuous improvement efforts especially in terms of production activities.

4.2. Process-centered management

The analysis showed that effective communication is significant to eliminate physical (e.g.: materials, equipment, cost) and non-physical waste (e.g.: time, effort and commitment). It helps to optimise the workflow of an organisation and the final product that needs to be delivered to meet the project objectives. Process-centered management can help to improvise the communication between parties in the IBS application by organising workers into multidisciplinary teams whose goals are focused on

managing the end-to-end activities that deliver value to customers. Production workflows dealing with IBS components is require proper planning and coordination. The success of IBS implementation only can be achieved if the system is professionally managed and handled [15]. The analysis revealed that effective planning and better coordination are also vital to improve the current productivity in the manufacturing of building components. Effective planning includes work planning and studying work method alternatives to optimise resources available [16]. Improving the information flow network can also improve problem solving through transparency and mutual understanding among employees. It is critical to have collaboration among employees to improve and smoothen the process of information exchange. However, the contractors and local authorities have distinct perspectives in terms of information delivery. Normally, the authorities possess the knowledge to influence a decision. In addition, authority and communication protocols are clearly established to maintain the authority of the general contractor. Fundamentally, activities are treated as "black boxes", where the means and methods for work are left to the specialty contractor [16]. Therefore, effective communication is a critical issue which should be handled by organisations to overcome uncertainties and to improve their workflow.

4.3. Training and education

In order to ensure the success of lean thinking, employees in an organisation need to be equipped with appropriate skills and knowledge. Most workers fail to understand the benefits of lean thinking in IBS implementation. The lack of education and insufficient knowledge will become a resistance towards change [17]. Failure in recognising value-added and non-value added activities will also lead to waste in the production workflow. Additional cost and extra time will be needed if the employees are not able to understand the fundamental concepts of lean thinking. The findings also show that employees prefer to stay in their comfort zone and refuse to adapt to change or operate in a new diverse environment [18]. Therefore, exposure to lean education and knowledge is vital to critically overcome these barriers.

5. Conclusions

Obtaining the feedback of the stakeholders in the construction industry on the potential of lean thinking in IBS implementation is vital to ensure that the implementation of the modern construction method is systematic and structured. This study has identified the CSF of lean thinking and IBS. A basic relationship between each identified factor has also been formulated to deliver the best output for the construction industry in Malaysia. The five principles in lean thinking need to be focused on in the production process. The study found that some organisations have different views in terms of the implementation of lean thinking in IBS. The conflict between different stakeholders needs to be solved by providing a better understanding of lean thinking. Next, a guideline on managing IBS construction can be developed via a qualitative approach to investigate how CSF can help to optimise the productivity of building components.

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