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Research paper

Insights into The Adoption of Lean Management in Industrialised Building System (IBS) Implementation: The Drivers and Challenges

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Abstract

The application of lean management is able to improve construction processes. Unnecessary waiting time, overstaffing and risk uncertainty are some of the problems that can be eliminated by adopting lean management. Industrialised Building System (IBS) is a sustainable approach that can be improved construction deliverables with the integration of lean management. However, the adoption or practice of lean management in productions of IBS component productions is still limited. There are only few studies emphases on the interactions among key drivers and hierarchy of lean management key drivers model. This study used Interpretive Structural Modeling (ISM) to interpret relationship of drivers and challenges in integrating lean management in form of ISM based-model and *Matrice d'impacts croisés multiplication appliquée an classment* (MICMAC). The results from this will improve the adoption of lean management in IBS application.

Keywords: *Interpretive structural modelling; lean construction; prefabrication.*

1. Introduction

Construction industry plays a significant role in contributing to the growth of Gross Domestic Product (GDP) [1]. In Malaysia, the implementation of Industrialised Building System (IBS) have a potential to keep the GDP of the country at the promising state [2]–[5]. IBS is a highly competitive industry involving both construction and manufacturing processes. However, according to statistics, the construction industry still owns one of the lowest productivity levels in the economy. The relatively low productivity level is reflecting the low uptakes of modern technologies and practices. The use of modern technology or productivity tool originated from lean concept is able to increase productivity and competitiveness of all IBS practitioners in construction by lowering the production cost through economies of scale [6]. The application of lean techniques able to manage construction processes with minimum cost and maximum value by considering customer needs [7], reduce complexity within design phase [8], and hence providing proper management strategy to drive efficiency and contribute to higher productivity for both construction and manufacturing sector by operational excellence [9].

However, adoption or practice of lean management tool in IBS component productions are rather vague. The failure of the government to encourage and involve the participant of small and medium components producers resulting monopoly of manufacturers, thus increasing the price of IBS components and tender pricing. To date, until March 2017, there are only 218 IBS manufacturers and 17 distributors were registered in Malaysia. Majority of these manufacturers are single plant operators concentrated in selected states only. Most of them propagate their own proprietary system, do not operate in full capacity, and have difficulty meeting the demands of contractors. The majority of locally developed products are based on traditional material, such as reinforced concrete, and most innovative materials used are based on imported technology.

On the whole, awareness on lean management adoption among IBS practitioners is still in a halfway level. Hence, it is imperative to study on the possible reasons preventing successful of application of lean management in IBS application and the possible solutions to derive the full benefit of both IBS incorporating lean management method. The key drivers and main barriers elements of adoption of lean management in IBS was critically reviewed through extensive literature review. These elements have been studied in depth to match with the development of Malaysian construction industry scenario through personal interviews and open discussion involving local authorities, IBS manufacturers and contractors in Malaysia. Besides identifying the existing lean management tool adopted in IBS implementation, this study will assist construction players to improvise their manufacturing process in the implementation of IBS by revisiting key drivers' factors and overcoming barriers that forbidding this effort.

2. Malaysian Construction Industry

Effort made by the Malaysian government together with CIDB agency to urged the construction industry to switch to use IBS method from traditional method has started since 2003 through the introduction of IBS Roadmap 2003-2010 to promote a cleaner, safer, simpler and more efficient method of construction. After a decade of continuous encouragement, monitoring and assessment made by the Malaysian government and CIDB, the use of IBS in Malaysia has increased, resulting in numerous housing projects in the past years. Besides that, the rules set by the Malaysian government mandating the use of IBS components up to 70% in year 2008 and full industrialisation by 2010 has also contributed towards the increased use of IBS method [10]. In the latest IBS Roadmap 2011-2015, the government is focusing to sustain the existing momentum 70% IBS content in public sector meanwhile 50% IBS content in private sector building project. However, it was discovered that smaller contractors tend to view IBS as thread rather than an opportunity.

Construction Industry Transformation Programme (CITP) 2016-2020 is one of Malaysia's national agenda in transforming the construction industry to be highly productive, environmentally sustainable, with globally competitive players while focused on safety and quality standards. However, the construction industry still has one of the lowest productivity levels in the economy. This relatively low productivity level reflects the industry need to adopt modern technologies and practices. Extensive use of modern and high technology tools is able to support the different IBS processes by enabling more accurate documents and hence good conditions for an effective production where errors are discovered early and problems in the manufacturing and assembly phases can be avoided [11]. This programme is encouraging utilisation of modern construction methods together with the support of appropriate technologies to address productivity challenges in the industry.

2.1. Lean Management Practice in the IBS Construction Industry

Lean management is defined as a philosophy based on the concepts of lean manufacturing for managing and improving the construction process to profitably deliver what the customer needs [12]. Lean management has the ability to improve the project coordination and eliminate unnecessary process causing waste in construction. It is an integrated system concerning the project principles, practices, tools, and techniques to reduce the cost and waste generation from all kinds of resources [13-14]. This concept is believed able to assist manufacturers and contractors to achieve the maximum value from the production or installation process and minimise waste [15].

Lean management received wide attention among academicians, construction practitioners and government agencies since last few years. With increasing focus on productivity and performance within construction, the management strategy to drive efficiency and contribute to higher productivity by operational excellence is vital. For example, by raising the enablers for IBS adoption such as by introducing lean management application as one of productivity tool to drive efficiency and contribute to higher productivity. Lean management approach can produce better construction environment with far better cooperation and far less conflict [16].

An approach to making construction lean is by modularisation [8]. In Malaysia, modular coordination was used to coordinate the dimension and spaces as a standard of measurement for IBS elements. The building and its components are being dimensioned and positioned in a basic unit or module known as 1 M which is equivalent to 100 mm [17]. The implementation of modular coordination concept towards design in prefabricated components can enhance the total constructability in the construction project [18], improved flow, and resulting greater flexibility as advantages obtained from standardization [19]. However, the adoption of this standard is still low due to misconception and lack of motivation to use modular coordination [20].

Just in Time (JIT) is a product pull system that responds to actual customer resulting lower inventory of raw materials, less work in process, and shorter lead time depending on very high quality and reduced setup time within production process [21]. The application of JIT or philosophy in precast concrete components has been proved to bring a significant result in Japan construction industry [22]. JIT practise in precast IBS component offers easier and quicker erection of the building structure [23]. However, some organisation still has trouble implementing JIT due to high initial investment [24], lack of precise contractual agreements and lack of top management commitment [21].

Building Information Modelling (BIM) is defined as an approach to building design and construction through modelling technology, associated set of processes and people to produce, communicate and analyse building information models [25]. The application of BIM in IBS project facilitating problems solving at the early stage of a project lifecycle. However, flow and deliverable rely heavily on computer-aided design (CAD), which is not conducive to support a model-oriented process.

The usability of lean management as tool strive for operational excellence has been presented in a manual book for construction players consideration as the result from discussions between CIDB and Malaysian Productivity Corporation (MPC). However, the adoption of lean management is still low due to some challenges such as high consultation cost, misconception and lack of details guidelines.

An interview session was conducted with MPC agency and CIDB agency representatives to discover the level of acceptance and current implementation of lean concept in the IBS practise. The implementation of lean culture is still in the average stage [26] even though the application of lean culture has proven to give advantages in streamlining production processes and increase productivity

2.2. The Key Drivers and Main Barriers for Lean Management Application

Application of lean management in construction industry has started since early 1990s by Koskela. It is as an effort to enhance construction project flows. Main driver of integrating lean management is client, labour, organisation and time aspect. Issues on construction culture which was too activity oriented affecting a construction value. Failure of construction practitioners in identifying added value and non-added activities has been set as key drivers in applying lean management culture. By definition, value-added activities provide desirable outcomes for a customer meet the customer's value proposition meanwhile, non-value-added activities do not contribute to meeting a customer's expectations. For example, searching for a tool to perform a task does not get the task done and does not provide value [27]. One of the production core philosophy is 'flow'. Flows are characterised by time, cost and value. Neglecting flows in construction process can triggered delay in project starting with slow approvals from clients, late appointments of consultants and shorter time to complete the design documents [28]. This fragmentation problem causing longer flow and higher requirements for cooperation and coordination, longer error correction cycles causing large correction costs and tolerance problems [29].

However, there are some challenges faced by the industry in applying lean management. Some of the main challenges are subjected in the technical, labour, cost aspect which is absentees of modularisation in prefabrication. Prefabrication offers the potential to reach many of the goals of lean management. It can reduce waste on site in terms of labour and materials; it can increase quality and reduce uncertainty [30].

Modularity also deliberates process related effects and can thus ease the implementations of lean management principles [31]. However, most of manufacturers is struggling in applying modularisation in the components design [31]. This issue leads higher internal complexity in productions. Besides that, design process involving incomprehensive prefabrication can cause large on-site tolerance which need of further alteration [30] and poor in material detailing [8], [32].

Indefinite work structuring on project building understanding is also known as a barrier in lean implementation. Improper work structuring often resulting high cost of transportation and installation for modularisation [33], [34].

Table 1: Key drivers of lean application

Key drivers initial	Key drivers of lean application	Ref.
Planning	Proper planning can avoid congestion of flows in the construction	[35]
Create responsible labour	Good attitude creating more responsible labour	[38]
Enhance construction process	Improve construction process to profitably deliver what the customer needs	[32,44]
Safer workplace	Safer workplace requires standard procedure for each machinery and equipment operations	[46]
Accentuate customer satisfaction	Construction quality influencing customer satisfaction	[42]
Develop strong organisation	Teamwork will create strong organisation culture	[41]
Educate labour	Appropriate training and education will deliver lean educated labour	[39]
Modularisation	Modular approach enables easier management of deliveries, scheduling and quality	[8]
Awareness	High awareness from top management is important to increase public awareness	[47]
Standardisation	Stable production design is vital to standardise process, workload and organisation	[36]
Lean design	Lean design promotes different views to model for better analysis and understanding within design process	[37]
Operational process	Labour competence implies the excellence of operational processes	[40]
Systematic control	Provide standard IBS working condition	[16]
Increase competitiveness	Improve business competitiveness performance	[49]
Reliable supply chain	Creating more reliable supply chain between customer in coordination with project team	[43]
High commitment	Construction requires higher level of commitment and involvement of top management	[45]
Use better facilities	Customer are demanding for better facilities	[8]
Reduce production time	Reduce process time spent to produce parts or components into a useable product desired by customer	[48]

Table 2: Barriers of lean application

Barriers initial	Main Barriers of lean application	Ref.
Expensive consultation	High professional consultation or coaching cost	[23], [50] & [51]
Refuse to change	Refuse to adapt change in culture and dependency on foreign workers	[52]
Organisation initiative	Lack of legislation and policy stressing on lean practice	[53] & [35]
Tools and technique	Lack of transparency, integrated agreement and flexibility in adopting appropriate lean tool	[54], [55] & [48]

3. Methodology

A combination of both quantitative and qualitative methods was applied in this research. Questionnaire survey and semi-structured interviews were adopted to identify influence factors of lean management technique in eliminating waste for IBS construction. All the influencing factors level of significant were obtained throughout the questionnaire survey. By using IBM SPSS Statistics software version 22, the ranking of influencing factors was carried out based on their mean values and one sample t-test analysis. Cut-off mean value of 4.00 were made [56] indicating "significant" where out of the 51 factors identified from literature review, only 46 were rated by the respondents as "significant" and "very significant" (mean $\geqslant$ 4.00). All the 46 factors were then tested with t-test to identify a critical rating of factors, t-value of 1.68023 with confidence interval percentage of 95% (α= 0.05) was set and resulting 18 critical factors remained. Table 3 indicated the ranking of critical influencing factors to adopt lean management application in IBS construction.

Table 3: Ranking of critical influencing factors to adopt lean management application in IBS construction.

No	Critical influencing factors	N	Mean	SD	t-value	df	p-value
1	Planning	45	4.49	0.626	5.239	44	0.000
2	Create responsible labour	45	4.42	0.723	3.919	44	0.000
3	Enhance construction process	45	4.33	0.739	3.028	44	0.004
4	Safer workplace	45	4.33	0.707	3.162	44	0.003
5	Accentuate customer satisfaction	45	4.31	0.793	2.633	44	0.012
6	Develop strong organisation	45	4.31	0.701	2.976	44	0.005
7	Educate labour	45	4.31	0.701	2.976	44	0.005
8	Modularisation	45	4.31	0.633	3.296	44	0.002
9	Awareness	45	4.29	0.895	2.165	44	0.036
10	Standardisation	45	4.24	0.679	2.413	44	0.020
11	Lean design	45	4.24	0.645	2.542	44	0.015
12	Operational process	45	4.22	0.636	2.345	44	0.024
13	Systematic control	45	4.22	0.670	2.223	44	0.031
14	Increase competitiveness	45	4.20	0.661	2.031	44	0.048
15	Reliable supply chain	45	4.20	0.757	1.773	44	0.083
16	High commitment	45	4.20	0.661	2.031	44	0.048
17	Use better facilities	45	4.20	0.726	1.848	44	0.071
18	Reduce production time	45	4.16	0.601	1.735	44	0.090

Consecutively, in order to provide a better understanding on the associations of these factors, semi-structured interviews were conducted in this research using Interpretive Structural Modeling (ISM) method. The interviewees are including government bodies of lean experts from MPC government bodies and CIDB officers. In addition, IBS manufacturers inclusive IBS contractors which are considered as top players in the country with higher technology investment are also interviewed. Details on interview participants are shown in Table 4.

Table 4: Detail of respondents

Interviewee	Positions	Organisations
Interviewee 1	Senior Manager	Government agency
Interviewee 2	Consultant	
Interviewee 3	Consultant	

Interviewee 4	Consultant	
Interviewee 5	Project Manager	Government agency
Interviewee 6	Assistant Engineer	
Interviewee 7	Assistant Manager	
Interviewee 8	Engineer	Contractor A
Interviewee 9	Resident Engineer	Contractor B
Interviewee 10	Director	IBS Manufacturer A
Interviewee 11	Production Manager	IBS Manufacturer B
Interviewee 12	Manager	IBS Manufacturer B
Interviewee 13	Sales Executive	IBS Manufacturer C
Interviewee 14	Engineer	IBS Manufacturer D

The ISM method was very useful in developing a relationship between factors among the element of a system [20]. In this study, associations between all the influencing factors were built by considering on participants thoughts, industrial knowledges and technical understandings.

Table 5 shows on how SSIM matrixes were developed by specifying SSIM with letter V, A, X or O constituting reachability matrix (RM) which converting the relationship denoted by V, A, X and O to 1 and 0 [57].

Table 5: The SSIM indicators relationship between variables

SSIM	(i, j)	RM
V	Factor i will lead to Factor j	eij = 1 while eji = 0
A	Factor i will be achieved by Factor j	eij = 0 while eji = 1
X	Factor i and factor j will help achieve each other	eij = 1 while eji = 1
O	Factor i and factor j are not related	eij = 0 while eji = 0

The transitivity of matrix need to be first checked before the final reachability matrix can be established. By the rule of thumb, transitivity is determined by studying the relationship of SSIM where when factor A is related to B and B is related to C, then A is essentially related to C [58-59]. The outcome for final reachability matrix which underwent transitivity analysis was presented in Table 6 together with the summation of driver powers and dependence powers of all factors. The strength of each critical influencing factor was indicated by the number of its driver power. The driver power represented the factors' strength in achieving another critical influencing factor. Meanwhile, the dependence power indicated the degree of the factor be contingent upon other factors.

The reachability set and antecedent set of each factor in this study was identified based on the final RM. The RM set comprising a reflexive factor and its drive factors. Meanwhile for antecedent set, it comprises a reflexive factor of itself and the factors on which it depends on [60]. Factors with the most identical sets of reachability and intersection were labelled as top-level elements which located at the top ISM model. After several iterations made and shown from Table 10, seven levels iterations were formed and structured into the ISM model. These seven levels ISM based are visualised in Figure 1.

4. Results and Discussion

The survey studied total of 18 critical factors which were previously identified from extensive literature review. Respondents were required to rate the level of significance of each factor based on their own perspective, experience and knowledge. The respondents were representing government bodies, IBS manufacturers and contractors which work nature involving productions of IBS components and constructions. Table 3 shows the statistical results for factors having t-values greater than 1.68023 were outlined as the critical influencing factors for lean management application in IBS construction. As a results, there are 18 "significant" influencing factors which are 1) planning, 2) create responsible labour, 3) enhance construction process, 4) safer workplace, 5) accentuate customer satisfaction, 6) develop strong organisation, 7) educate labour, 8) modularisation, 9) awareness, 10) standardisation, 11) lean design, 12) operational process, 13) systematic control, 14) increase competitiveness, 15) reliable supply chain, 16) high commitment, 17) use better facilities and 18) reduce production time.

Then, the ISM analysis takes place by categorising the main aspects involved in current lean management application such as the driver factors and challenges faced by the industry and some potential strategies that can be recommended by IBS major player for other company future references. The key aspects have been highlighted are clients, labours, organisation, technical, time, cost, tool and technique. All the interviewees were asked questions based on Structural self-interactive matrix (SSIM) conception. All interviews were conducted by implementing face to face interview. The results for SSIM categorized by IBS players are indicating numerous achieving factors (A), followed by leading factor(V) and related factors (X). The least denomination factors are not related factor (O).

Table 6: Final reachability matrix with applied transitivity

0	No	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Driver power
Planning	1	1	1*	1	1	1	1	1	0	0	1*	0	1	1	1	1	1	1	1	15
Create responsible labour	2	0	1	0	0	0	1	1	0	0	1*	0	1	1	1	1	1	1	0	10
Enhance construction process	3	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	1	0	1	0	0	14
Safer workplace	4	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	0	1	1	0	0	15
Accentuate customer satisfaction	5	0	1*	1*	1*	1*	0	0	1	1	0	1	0	0	1	1	0	0	0	9
Develop strong organisation	6	0	1*	1*	1*	1*	1*	0	1	1	1*	1	1*	1	1	0	1	0	0	13
Educate labour	7	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	14
Modularisation	8	1	1	1	1	1	1	1	1	1	1*	1	0	0	0	1	1	1	1	15
Awareness	9	1	1*	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	16
Standardisation	10	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	13
Lean design	11	1	1*	1*	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	12
Operational process	12	1	1*	1*	1*	1*	1	1	0	0	0	0	0	1	1	1	0	0	0	10
Systematic control	13	1	1*	1*	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	10
Reliable supply chain	14	0	1	1	0	1	1	1	0	0	0	0	0	1	1	1	1	1	0	10
Use better facilities	15	1	1*	1*	1	1	1	1	0	0	0	0	0	1	1	1	0	1	0	11
High commitment	16	1	1*	1	1	0	0	1	0	0	0	0	0	1	1	1	1	1	0	10
Increase competitiveness	17	1	1	1	1	0	1	0	0	0	1	0	1	1	0	1	0	0	1	10
Reduce production time	18	1	1*	1	1	1	1	1	0	0	1*	0	1	1	1	1	1	1	0	5
Dependents		14	16	16	14	14	15	13	9	8	9	7	7	13	13	15	13	10	6	

Table 7: Summary of iteration for all level partitions

No	Factor	Reachability set	Antecedent set	Intersection	New level
1	Planning	1,2,3,4,5,6,7,9,12,13,14,15,16,17,18	1,8,9,10,11,17	1,9,17	5
2	Create responsible labour	2,3,4,5,6,7,9,12,13,17	1,2,8,10,11,13,14,15,16,18	2,13	6
3	Enhance construction process	3,5,7,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,6,7,8,9,10,11,13,14,16	3,7,8,9,10,11,13,14,16	1
4	Safer workplace	3,4,6,7,8,9,10,11,12,13,14,15,16,17,18	1,2,4,5,7,8,9,10,11,12,13,14,15,16	4,7,8,9,10,11,12,13,14,15,16	1
5	Accentuate customer satisfaction	4,5,8,10,11,14,15,16,17	1,2,3,5,6,7,9,12,13,14,15,16,18	5,14,15,16	4
6	Develop strong organisation	3,5,6,7,8,9,10,11,13,14,15,16,17	1,2,4,6,7,9,12,13,14,15,16,17,18	6,7,9,13,14,15,16	1
7	Educate labour	3,4,5,6,7,8,9,10,11,13,14,15,16,18	1,2,3,4,6,7,17	3,4,6,7	1
8	Modularisation	1,2,3,4,8,9,10,11,12,13,14,15,16,17,18	3,4,5,6,7,8,9	3,4,8,9	3
9	Awareness	1,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18	1,2,3,4,6,7,8,9,17	3,4,6,8,9,17	3
10	Standardisation	1,2,3,4,10,11,12,13,14,15,16,17,18	3,4,5,6,7,8,9,10	3,4,10	3
11	Lean design	1,2,3,4,11,12,13,14,15,16,17,18	3,4,5,6,7,8,9,10,11	3,4,11	3
12	Operational process	4,5,6,12,13,14,15,16,17,18	1,2,3,4,8,9,10,11,12,13,14,15,16	4,12,13,14,15,16	4
13	Systematic control	2,3,4,5,6,12,13,16,17,18	1,2,3,4,6,7,8,9,10,11,12,13,14,15,17	2,3,4,6,12,13,17	2
14	Reliable supply chain	2,3,4,5,6,12,13,14,16,17	1,3,4,5,6,7,8,9,10,11,12,14,15,18	3,4,5,6,12,14,	2
15	Use better facilities	2,4,5,6,12,13,14,15,16,17,18	1,3,4,5,6,7,8,9,10,11,12,15,16,17	4,5,6,12,15,16,17	2
16	High commitment	2,3,4,5,6,12,15,16,17,18	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	3,4,5,6,12,15,16,17	2
17	Increase competitiveness	1,4,6,7,9,13,15,16,17,18	1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17	1,4,6,9,13,15,16,17	5
18	Reduce production time	2,5,6,14,18	1,3,4,7,8,9,10,11,12,13,15,16,17,18	18	7

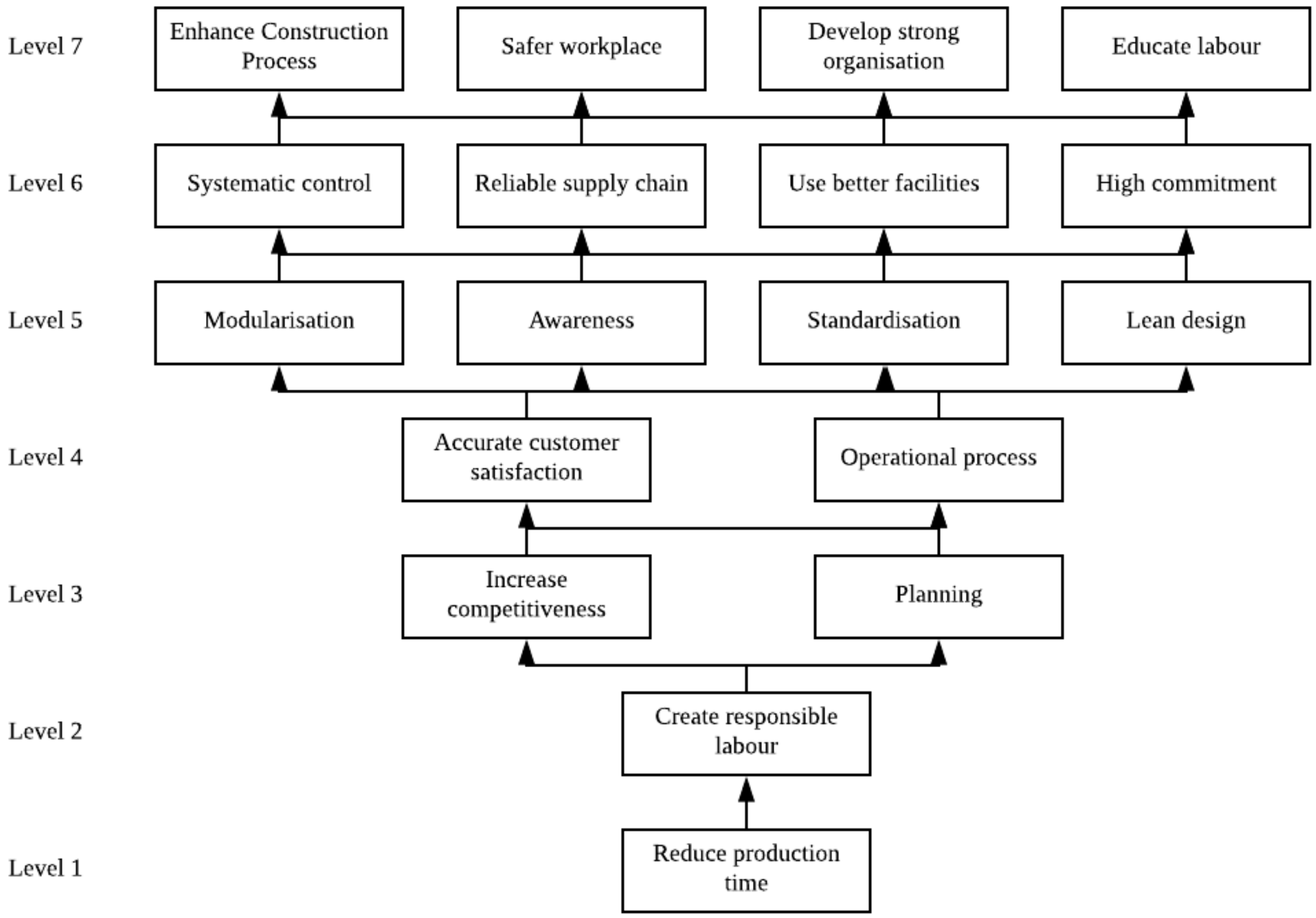

Fig. 1: ISM model of interrelations among critical success factors of lean management in IBS construction application

4.1. ISM Based Model Analysis

ISM Model formulation on critical influencing factors of lean management application in IBS construction. Based on ISM model shown in Figure 1, “reduce production time” was located at the bottommost position. It was the primary factor that extends the other factors in the ISM system. According to top managements of most IBS factory, clients are expecting speedy action from manufacturers for a project using modern construction method, IBS. IBS is known as a fast track completion project where clients are expecting fast productions of building components with the aid of mechanisation and automation [61].

On top of the factor is “Create responsible labour” which is related to the reducing production time effort. In order to make the effort succeed, each person in the organisation need to play their role seriously and be very responsible in striving goal sets and also in fulfilling clients’ requirement. Each employee mentioned are including top management, middle management and skilled labours. In this stage, with support from top management with good leadership, an information flow in the production process can be effectively managed. In addition, teamwork among employees along with their good commitment are vital to ensure that every people work together in a very coordinated and supportive way. The presence of trust and appropriate tools will keep the team to better aligned by developing a charter with production core values which result in faster decision making that may increase productivity.

Factor located at the third bottom position of the model is “Planning”. Normally, it was general manager, project manager and production manager role to ensure strategic planning of a project and better production flows. Systematic and proper planning of certain project from an organisation at the same time will be able to “increase competitiveness” of the factory itself among many other suppliers.

Factor located at the forth bottom position of the model is “Accentuate customer satisfaction” and “operational process”. Normally, in a project case study, customer prone to choose manufacturers to supply building components according to the factory excellent operational process. Good operational process will never fail to give customer satisfaction as their demand to get a fast action from manufacturers were fulfilled.

Factors located at the fifth bottom position of the model and related to each other were “Modularisation”, “Standardisation”, “Lean design” and “Awareness”. The effort to reduce production time can be achieved by lean design. According to most IBS manufacturer, lean design is a part of enabler in standardisation of working procedures and modularisation in building components design. Therefore, in their opinion, high awareness of all these three elements will brings more returns in term of cost and time. Basically, standardisation of work especially dealing with the use of machineries and other automation medium will be able to reduced setup time, waiting time and other motion time. Meanwhile modularisation or design using modular coordination will be able to create flexibility in term of least customisations, formworks are reuseable, encourage design and operation repetitions, components arrangements which are all approaching on the utmost goal of reducing the overall cost of construction when it was massed produced in multiple repeated units.

Factors located at the sixth bottom position of the model and related to each other were” Use better facilities”, “Systematic control”, “High commitment” and “Reliable supply chain”. Most manufacturer acknowledged lean tools and technique as facilities. Facilities that usually preferred by manufacturers is a systematic control-based. According to most participants, the adoption of any tools, technique or facilities requires high commitment from all employees to make it work. Some of lean tools promising reliable supply chain. According to manufacturers, one of the customer accentuation is reliability of supply chain between clients and suppliers for them to ensure zero defects in production, zero overproduction and unnecessary processing capacities, no inventories, no unnecessary movement of people and goods, and employees that clients will never need to wait.

“Enhance construction process”, “Develop strong organisation”, “Educate labour” and “Safer workplace” were located at the uppermost level of the ISM. This result indicated that these highest-level factors were having either direct or indirect relationship with all other factors. For example, construction process can be enhancing by reducing production time, through strategic planning and adoption of appropriate lean tools or techniques. “Safer workplace” can be obtain through systemic control-based management. A “strong organisation” will “increase competitiveness” meanwhile lean “educated labour” can assist company to “enhance construction process” by having knowledge on implement lean culture.

4.2. Matrice D’impacts Croisés Multiplication Appliquée An Classment (MICMAC) Analysis

MICMAC analysis was conducted to examining the resemblances of all factors concerning the ISM model in four cluster groups namely 1) autonomous, 2) dependent, 3) linkage and 4) independent. The MICMAC results were shown in Figure 2.

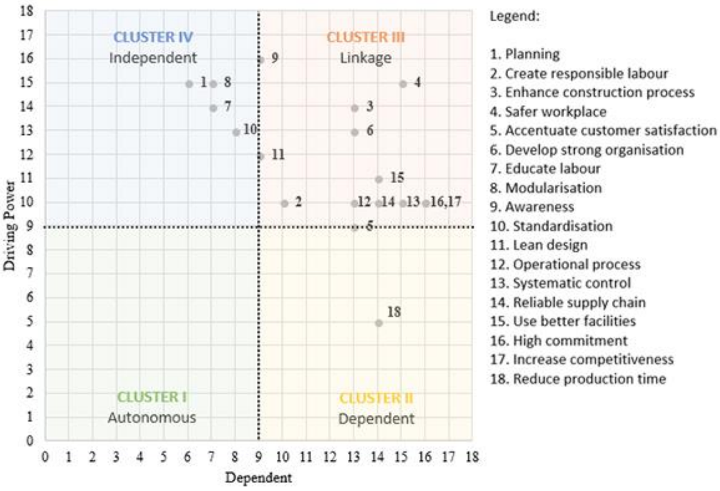

Fig. 2: Driving power and dependence diagram

The first cluster of MICMAC analysis placed at south- west quadrant indicated the autonomous group of critical influencing factors of lean management integration [62]. All the factors which lies in the autonomous categories are having both weak driver power and weak dependence power where they are comparatively uncoordinated within the system but with few possible strong links [63]. These autonomous critical influencing factors of lean management integration are disengaged in a relative manner towards all the other critical influencing factors. In this study, there are no critical influencing factors lied in autonomous group.

The second cluster representing critical influencing factors of lean management integration with dependent criterions which were weak in driver power however it owned strong dependence power. High driver powers of a factors representing its tactical elements whilst high dependence powers of a factor representing performance elements [64], [65]. In this study, “reduce production time” factors lie in the dependence cluster. In addition, a linkage factor of “accentuate customer satisfaction” lies in the border line in between dependence-linkage cluster. This group of critical influencing factors of lean management integration requires IBS manufacturers for undergoing ultimate change and improvement in their current operational culture, work organisations, and considering deeper investigation as effective reduction of production time is possible only if other critical influencing factors are effectively implemented.

The third cluster is showing all the linkage cluster for critical influencing factors of lean management integration which having both strong driver power and strong dependence power. All the critical influencing factors located in linkage group were classified as unstable. These factors are in all likelihood can be affected by any action where the impact will include on others factors and also on the factor itself either to amplify or support [66]. critical influencing factors of lean management integration that lies in linkage clusters are known as “Create responsible labour”, “Enhance construction process”, “Safer workplace”, “Accentuate customer satisfaction”, “Develop strong organisation”, “Awareness”, “Lean design”, “Operational process”, “Systematic control”, “Reliable supply chain”, “Use better facilities”, “High commitment”, and “Increase competitiveness”. It implies that these factors have the most influence on the critical influencing factors thus making them as focal point of concentration for the implementation in lean-IBS integration application.

Fourth cluster considered as the most important variables. Critical influencing factors of lean management integration lies in this group are having strong driving power but weak in dependence power [64], [65]. For the categorised critical influencing factors of lean management integration lies in this independent cluster are known as “Educate labour”, “Modularisation”, “Standardisation” and “Planning”. In addition, the contiguous linkage factor from the third cluster linked to the fourth cluster are “Awareness” and “Lean design”. These are fundamental factors that stimulates other factors towards the successfulness of lean management culture in IBS application. Implementation of lean culture in production requires lean educated employee as their knowledge was reflecting their behaviour, involvement and commitment which lead for greater contribution in identifying and reducing waste. The modularisation, standardisation and planning are enshrined as technical aspects. This is in line with previous study which stated that most management approaches in construction are technically-oriented methodologies which making these two critical influencing factors as important as a lean awareness and improvement effort.

5. Conclusion

From the whole ISM analysis findings, the driving forces and dependencies pressure of production process in IBS application do associated and required careful attention in achieving successful application of lean management with the most important related links from an overall production perspective. The driving factors in adopting lean management in this study are planning, educate labour, modularisation and standardisation. It shows that the integration of lean management should be started at the initial stage including design and scheduling. The workers especially at the project level should be familiar with the concept to ensure the successful in completing IBS projects.

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