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Workspace Planning Process Model for Industrialised Building System Projects

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ABSTRACT
Background: The method of conventional construction activity planning has not been able to provide space panning requirements at the constructions sites. This is also the case for the existing space planning technique which does not offer full solution in considering the types of the construction method as in the IBS. This planning technique also necessitates highly-skilled users, the use of technology system application techniques and complex mathematical formula causing it to be less practiced in the IBS construction environment and easier and more effective space planning technique. **Objective:**Therefore, this study has focused on the workspace planning process model development towards the implementation of the IBS construction projects. **Results:** The proposal for the workspace planning model has been established in the form of short-term documentation. It is constructed through a combination of quantitative and qualitative findings basing them on the brainstorming of various ideas of the planners involved directly at the site. Five stages of the planning process have been arranged by accounting for the aspect of the space-type and methods of solution for the interference and workspace conflicts at the site, in a systematic way, and which is able to help the contractors mitigate these problems at the site. The content of the model constructed is evaluated by nine experts from various fields via face-to-face interviews using a questionnaire form. **Conclusion:** Positive feedback from all the members of the panel depicts the conclusion that the model content is capable of providing a detailed, comprehensive, all-round, and applicable workspace planning for the actual IBS construction environment.

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INTRODUCTION

Construction activity planning methods such as the Gantt Chart and Bar Chart, Critical Path Methods (CPM), Program Evaluation and Review Technique (PERT), and Line of Balance (LOB) do not seem to be powerful enough in addressing the issue of using the space resources at the site (Mawdesley et al., 1997; Arditi et al., 2002; Heesom, 2004; Dawood and Mallasi, 2006).The space at the site, if not planned more efficiently,should be able to create work space disturbances and conflict and give a negatif impact to productivity, work quality, constructability, damage, safety and project's duration of completion (Thabet and Beliveau, 1994; Riley and Tommelin, 1996; Riley and Sanvido, 1997; Guo, 2002; Jang, 2002; Akinci et al., 2002a,c; Dawood and Mallasi, 2006; Mallasi, 2006; Winch and North, 2006; Hammad et al., 2007; Aduagyei, 2008; Chua et al., 2010; Bansal, 2011). Additionally, if it involves construction projects that involve the adoption of the method named the Industrialised Building System (IBS), a more dynamic and properly arranged workspace planning would be needed. Components produced through the IBS are large, heavy, and they need appropriate logistics equipment and planning including space resources for the handling and installing the components at the site.Earlier studies done in Hong Kong (Jaillon, 2009), Singapura (Pheng and Chuan, 2001), and Malaysia (Chung, 2006; Mian, 2006; SalihudinHassim et al., 2008; Jaganathan et al., 2013) report that workspace serves to be an issue that is able to give a negative impact to the effectiveness of the work and risks in IBS projects if the aspect of space fails to be attended to by the contractors in the work planning at the construction sites.

Studies focusing on the aspect of the workspace include those by Riley and Sanvido(1995) , Akinci et al. (2002a), Guo (2002), Winch and North (2006), Dawood and Mallasi(2006), also Bansal (2011). The studies have managed to offer a problem-solving approach in identifying, and reducing distractions and conflicts in the workspace. The contributions offered by these studies require the level that uses high applications either in the

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form of mathematical formula or computer system-based models.The lack of proper training by users on the models and the difficulty to get the outcome from the model analysis, are two factors that have rendered the aspect of workspace not very popular among the implementers. The high cost of implementation also impedes its use (Aduagyei, 2008). Additionally, these studies have focused on construction projects that center on the conventional system compared to the Industrialised Building System (IBS). This gives a slight gap towards the efforts to continuously enhance the productivity, quality, constructability, and safety aspects and making construction processes more sustainable. Therefore, this study has focused on the workspace planning process model development towards the implementation of the IBS construction projects.

Recent Research:

The review on the space planning technique at the site, in the macro, micro forms or the pathway begins with a traditional technique, which is by marking on the site drawing or site arrangement plan.This is to determine the space use for the placement of all facilities, like the office site, storage, construction component placement and also access.Other than that, the project manager adopts the daily activity arrangement technique based on the schedule that is already provided (Guo, 2002).One criticism towards this planning technique lies in the difficulty in identifying the probability for any space conflict to emerge and thus, leading to the problem frequently occurring at the site (Dawood and Mallasi, 2006). According to Mallasi and Dawood(2001), a traditional technique which involved the construction arrangement template in the form of manual sketching, bar charts, and network diagramwas not able to show in visual form the strategy and plan of the work activities, and the interactions between construction activities have contributed to the space conflict issues that affect the productivity of the construction, as a whole (Mallasi, 2006).

Innovation in the workspace planning technique preparation has given separate focus- macro, micro and pathway (Akinci, 2000).For the macro space planning, various approaches have been adopted such as the AutoCAD software applications, connected with the Microsoft Project software (Tommelein and Zouein,1993; Zouein, 1995; Riley and Tommelien, 1996; Choo and Tommelein, 2000); the geographical information system (GIS); the use of the Genetic Algorithm (GA) (Liang and Chao, 2008; Zhou et al., 2009; Huang et al., 2010; Ning et al., 2010); and the 3D and 4D technological visualisation approach (Heesom, 2004).For the micro space planning, the approach focuses on work operations, throughthe joint application of the project scheduling and work activities (Riley and Sanvido, 1997; Chua et al., 2010) through the CAD application model (Guo, 2002; Akinci et al., 2002a,b,c), and the system simulation (Heesom, 2004; Mallasi, 2006; Winch and North, 2006; Wu and Chiu, 2010). For the pathway planning, it functions as the movement of the construction materials, equipment, construction wastes and workers' access to facilitate and expedite the construction operations.The pathway closest to the operation areas, must be considered by project planners (Guo, 2001).Failure to provide a suitable, safe and close-by pathways has significantly reduced the level of productivity of the construction projects, especially in terms of the labour costs and time.The development of safe and closest pathway planning by Boffey and Karkazis(1995) has been prepared for the programming technique. It is developed to prevent any dangerous risks in the delivery of dangerous materials to the site. Varghese and O'Connor (1995) have used the GIS application and an expert system in determining the pathway suitable for the movement of large vehicles.The same technique is applied by Yang (2001) but he uses the approach of integration with the CAD graphic display.It seeks to identify optimal pathway for routine movement of construction materials at the site. Soltani and Fernando (2004) use the Fuzzy Logic approach in developing the model to measure and analyse the best and the safest pathway. Guo (2002) uses a different approach by considering the use of space by labours, equipment, construction materials and temporary structures. The technique combines activity scheduling and the AutoCAD application as an alternative to solving space conflicts and enhancing space use.Guo's approach (2002) has been concluded as comprehensive, as it considers the aspects of space overlap, conflict analysis, and the planning strategy proposal as to avoid conflict.

The existing space planning technique requires high level of skills of project planners or manager in using the model or planning system. Without specific training, planning tends to become more of a challenge and it will require the management to prepare advanced training and some financial allocations to fund the planning system development.In addition, most planning techniques have planning applications that involve information technology system and the use of complex mathematical applications. This technique also gives an advantage to only one individual, without involving other construction team members in the planning preparation.Such a complication is more imposed on the novice project planner or manager. Therefore, the workspace planning on-site, especially in theIBS environment necessitates a specific space planning technique, which enables all parties to get involved directly at the site in preparing for a more dynamic and specific planning.

MATERIALS AND METHODS

The workspace planning model has been developed based on the short-term planning in the form of documentation. The development of the model is done through the combination of positive approaches adopted by previous scholars like Aduagyei(2008), Riley and Sanvido(1997), Guo(2001), and Pheng and Chuan(2001). Inputs are obtained from quantitative findings which use new variables in IBS-environment based studies. Quantitative findings which are the inferential analysis outcome from the use of the regression weight value from the analysis outcome of the Structural Equation Model are derived from the analysis of the relationship on 168 IBS contractors (not described in detail in the present paper). The regression weight value is used to develop the Workspace assessment tool (WSAT). Qualitative findings come in the form of the analysis outcome of 8 IBS projects as the case study through interviews on space planning technique by the contractors and the type of interferences and workspace conflicts occurring at the sites (not described in detail in the present paper). The findings come to 17 types of interferences and workspace conflicts also 102 causes established in the case study.

The workspace planning model proposal's suitability and capability is assessed and revised in reducing the space conflicts in the IBS project environment. According to Adrian (2003) the measurement serves to be fundamental for the suggestion of improvement. Meanwhile, according to Thomas and Sanvido(2000), to enhance a system or technique, the effectiveness has to be evaluated. Without any point of reference, a technique or system would not prove to be useful if the proposal does not give any impact to anything that is to be improved (Hamlin, 1978).Therefore, the space planning model developed also looks into the model content.The assessment is referred to one that is used by Riley and Sanvido (1997) also Dawood and Malassi(2006). The instrument used to evaluate the model content is similar to the method used by Dawood and Mallasi (2006). The questionnaire form is constructed using the five-point Likert-scale which is; (1) = Strongly Disagree, (2) = Disagree, (3) = Neutral, (4) = Agree, and (5) = Strongly Agree. The questions are referred and adapted from Riley and Sanvido (1997), Dawood and Mallasi (2006), and Aduagyei (2008). Three groups of respondents are involved in this evaluation, based on criteria such as experienced and knowledgeable, experience of at least 10 years in the construction planning aspect using the IBS construction method; and able to fully cooperate (Fadhlin, 1999; Leedy and Ormrod, 2001; MohdHanizun, 2008). These respondents comprise of academicians at least of senior position (teaching and research), construction practice (project manager/construction planner/firm manager/construction contract manager), and the construction administrator from government bodies (senior manager/assistant manager and above).At this level, nine experts are needed to assess the model.Data obtained have been analysed quantitatively in the form of frequency and percentage descriptive statistics.

Workspace Planning Process Model for IBS Projects:

This model is built for a short term. It leans on the notion of all parties involved in the IBS project collaborating with one another.The combination of opinions and ideas of various parties- those with different information, knowledge, experience and skills are able to provide a more effective workspace planning.Radosavljevic and Horner (2007) suggest that the sharing of various ideas enables 50% contribution towards effectiveness. The parties that make up this space planning team are:

a. Project planner/ project manager (Lead);
b. Site engineer/ project engineer;
c. Logistic and materials manager;
d. Safety officer;
e. Client representative;
f. Sub-contractor IBS installer;
g. Trade; and
h. Crane operator.

The second concept is through the workspace planning principle utilization approach and planning guideline.The use of the principles is guided by quantitative and qualitative findings.Other than the findings serving as guidance for planning, the principles and guidelines for the space planning developed by previous researchers (Aduagyei, 2008; Riley and Sanvido, 1997; Guo, 2001; Pheng and Chuan, 2001) are also combined to produce a model that is able to reduce the number of distractions and conflicts of the workspace. The planning model proposal covers all categories of space which is the macro, micro and path spaces.

This model is work activity flow-oriented. It is developed for the workspace use planning at the site to ensure that the workspace can be of use more effectively. It is able to reduce the distraction and conflict of the workspace towards mitigating issues regarding productivity, constructability, and work quality also construction delay. The workspace planning process model is developed according to the sequence of these five main processes:

a. Process 1 – Workspace assessment tool (WSAT);
b. Process 2 – Pre-meeting (Information gathering);
c. Process 3 – Meeting 1 (Discussion, decision, scheduling, and documentation);
d. Process 4 – Implementation and monitoring the planning; and
e. Process 5 – Workspace conflict resolution.

This planning process begins in week n+1 to plan for work element n. This short-term planning is chosen as the previous analysis findings have exhibited some shortcomings. Other than that, there is the absence of detailed workspace planning prepared by contractors.In addition, contractors' existing planning technique does not seem to be capable in establishing any methodology on space planning and space conflict analysis. A short-term planning, is thus required to balance out unrealistic main plans, the often updated plans and also inaccurate plans to foresee the demands and possible distractions that can take place before the work begins.(Radosavljevic and Horner, 2007).However, all the procedures developed in the workspace planning process model are not specific to a project which happens to have different project traits. Notwithstanding, the approach adopted is the same.

Process 1: Workspace Assessment Tool (WSAT):

Before the planning begins, the input from the feedback obtained through the WSAT instrument is required. WSAT is a precursor to the general identification and assessment on workspace issues at the site. The outcome of this assessment will give the necessary information to the planners on the percentages of conflicts happening on-site (Aduagyei, 2008). A measurement instrument is used through the WSAT development, using the regression weight value (Table 1). WSAT as a set of questionnaire, contains 48 questions representing four independent variables which are Management issues, Jobsite planning, Resource and logistic, and Project characteristic and external environment issues. These variables represent factors for the weaknesses of the workspace planning that create the space conflict in IBS projects. Various parties such as the workers, client representatives need to make a sound evaluation on the current conflict by giving scores of 1-10. As a justification, an overall view needs to be gathered concerning the conflicts at the construction site. Through this assessment, situations of distraction can be studied. The total score of 100 will mirror the high level of workspace conflict and vice versa. Examples of calculation for this are given in Equation 1and Table 2.

Equation 1:

Management issues (X1- Communication and coordination) $= \dfrac{Regressionweight}{Sumof\ (Regressionweight)}$

$$= \frac{0.824}{7.106}$$

$$= 0.1159(11.59\%)$$

Table 1: Standardized regression weights.

			Estimate
X2	<---	Management issues (Decision making and team work)	.600
X1	<---	Management issues (Communication and coordination)	.824
X7	<---	Jobsite planning issues (Space sharing and construction method determination)	.685
X6	<---	Jobsite planning issues (Equipment and labour use planning)	.792
X9	<---	Jobsite planning issues (Space use determination)	.643
X12	<---	Resource and logistic issues (Availability of space and equipment)	.716
X11	<---	Resource and logistic issues (Material, logistics and arrangement of facility)	.700
X13	<---	Resource and logistic issues (Availability of materials and labour)	.845
X14	<---	Project characteristic and external environment issues (Weather, order of change, time and budget, and elements of uncertainty)	.612
X15	<---	Project characteristic and external environment issues (Project design, complex construction site, size and location of site)	.689
KRK2	<---	Workspace conflict	.812
KRK1	<---	Workspace conflict	.827

The total score of 51.49% shows that there are occurrences of workspace conflicts in the construction area. High-scored variables need to be given attention by the project manager or contractor management.Through WSAT, a rough picture of the potential of workspace conflicts will be more striking if there is no proper measure done by the management, especially in the aspect of workspace planning at the site.

Process 2: Pre-Meeting (Information gathering):

The second process for the planning (for work element n in week n+1) is to hold a pre-meeting. All the planning team members led by the project manager need to collect all details and information as to prepare for the planning. The project manager needs to brief his or her subordinates on WSAT analysis outcome also why workspace planning is necessary. The members need to take part actively in producing a more dynamic space planning and meeting the planning objectives. The following are the pieces of information that need to be compiled for the pre-meeting:

Table 2: Workspace assessment tool (WSAT) and calculation of interference and workspace conflict.

Item	Description	A. Weight (%)	B. Scores obtained (1-10)	C. Average score	D. Total score (A x C)
1	**Management issues**				
X1	**Communication and coordination**	11.59		4	46.36
	Failure in communication and coordination between the client causes inadequate work planning information		3		
	Communication breakdown between the management on site and at main office		3		
	Failure in communication and coordination between subcontractors causes insufficient information in the planning of work		6		
	Communication between construction team is not effective		4		
X2	**Decision making and team work**	8.44		3.25	27.43
	Lack of team work by management		4		
	Planner failed to decide planning of work activity and requirement of space utilization/resources		3		
	Inefficient site supervisor to manage work activities at construction site		3		
	Lack of dilution of supervision work activity at construction site		3		
2	**Jobsite Planning Issues**				
X6	**Equipment and labour use planning**	11.15		3.40	37.91
	Usage of high volume of cranes at work area		4		
	Disruption of machinery operation		3		
	Disturbance in equipmentoperation due to facility availability at work area		3		
	The high population of artisan at the workspace		4		
	Imbalance in the use of labour and employment size		3		
X7	**Space sharing and construction method determination**	9.64		6.66	64.20
	Co-operation between the sub-contractor		5		
	Contractor increases scope of work		8		
	Lack of planning in the control of subcontract's work in the work area		7		
	Engineering errors and miss-outs		4		
	Pressure in work completion or work acceleration causes space sharing to occur		8		
	Weak construction method/planning that does not consider use of workspace at construction site		8		
X9	**Space use determination**	9.04		4	36.16
	Collabouration between artisan cause overlapping use the same workspace		2		
	Number of corrective work / rework required to complete work makes use of the same workspace		6		
	Planning of critical construction activities with less emphasized on aspects of the use of space		4		
3	**Resource and Logistic Issues**				
X11	**Material, logistics and arrangement of facility**	9.85		6.25	61.56
	Planning schedule of the delivery of components / materials with the actual work schedule is not synchronize		8		
	Preparation of components (prefabricated) construction done at site		6		
	Planning of management of components / materials based on the concept of JIT is rarely used		9		
	Inefficiency in planning the use of equipment and machinery in the work area		4		
	Wrong delivery of components / materials by the supplier to the construction site		7		
	Unorganized facility arrangement at site		6		
	Movement of components / materials and equipment that is not properly managed		4		
	Placement of material at a distance far from the work site		6		
X12	**Availability of space and equipment**	10.07		6.50	65.45
	Non-availability of storage space for the placement of components / materials		7		
	Non-availability of handling space (placement of cranes, trucks) for the installation of construction components		7		
	Non-availability of path space for machinery, materials, and labour or the space for this aspect is not maintained by the management at site		7		

	Non-availability of machinery and equipment for the handling operation of components / materials which interferes with other work activities		5		

Table 2:*(Continued)*

Item	Description	A. Weight (%)	B. Scores obtained (1-10)	C. Average score	D. Total score (A x C)
X13	**Availability of materials and labour**	11.89		5.83	69.31
	Non-availability of adequate labour causes handling and assembly process to be disturbed		2		
	Non-availability of component / material causes handling and assembly process to be disturbed		6		
	Planning of space resource preparation does not emphasize on type and size of components/ materials or equipment/ machinery		5		
	Components/ materials is parked at the site for a long duration prior to being used causing space the site to be limited		7		
	Ineffective coordination between the suppliers and management at construction site		8		
	Operator with lack of experience and training in handling machinery at site		7		
4	**Project Characteristic and External EnvironmentIssues**				
X14	**Weather, order of change, time and budget, and elements of uncertainty**	8.61		4.5	38.74
	Limited construction time and budget causes increase in the usage of resources and work activities		4		
	Instruction to change by client cause disruption to other activities		3		
	Planning prepared without taking into account the element of uncertainty (congestion, traffic, etc.)		5		
	Bad weather prevents work activities		6		
X15	**Project design, complex construction site, size and location of site**	9.69		7.0	67.83
	Limited space at project site		9		
	The complex condition of the workspace makes it difficult for arrangement of facilities and workspace planning		7		
	Complex design projects complicate planning, scheduling, and space on site		4		
	Project site is located in urban areas or high-density		8		
				Total score	**514.95 (51.49%)**

a. Construction components and materials – knowing about the schedule of delivery of materials and components to the site to facilitate logistics aspects like the handling technique, machine preparation for offloading and placing, the use of labour, and determining the location of storage.The pathway needs to be prepared too to ease the process of moving the components and materials that have just arrived at the site.
b. Construction design – it influences and relates with the type of construction components and materials.It details the complexity of the type of building and the location of the building on the site arrangement. Information regarding the composition of building, floor level, room spaces in the building are needed for work arrangement, demand for construction materials' resourcesand the pathway.
c. Main activity scheduling – the information contained in the scheduling explains the timeframe needed to complete a project.Activity scheduling also explains the work activity arrangement according to logical sequence and the stipulated deadline for a given work element.
d. Construction method – In the IBS project environment, the construction method influences the smooth-running of the construction processes. Information on the construction methods and techniques is essential for space planning and use.
e. Safety aspects – construction activities are very vulnerable to risks and they are able to leave negative consequences to work safety, components and materials, also the workmen if this aspect does not receive adequate attention it so deserves.Information on the safety policy and action plan must be referred in this planning so that the emphasis on safety aspects can create a clean and well-protected construction environment. To add, IBS projects tend to use a lot of large and heavy components and high-capacity machinery.
f. Project constraint – it refers to aspects that are beyond the control or expectation of the contractors.Weather disturbances, limited space are some of the things that can become distracting in the workspace.

Process 3: Meeting 1 (Discussion, decision, scheduling, and documentation):

The next planning process is to have a meeting with all planning team members led by the project manager. The duration of meeting needs to be decided and used accordingly so that all the decisions made do not hamper the aims of the planning. In the meeting, all issues have to be discussed and decided by taking into account all requirements and expectations taking place in the work implementation. Some questions that arise may be as follows:

a. Type of work activity/work element?
b. Type of space available and needed?
c. Work method?
d. Demand for resources (space, labour, components and materials, machinery and equipment)?
e. Space behavioural pattern?
f. Work orientation pattern?
g. Potential for achievement (according to time and budget), space conflicts that may emerge?

On-site workspace planning for IBS-based projects necessitates an approach aptly called Just-in-Time (JIT). JIT should be fully exercised in the construction component and material logistics to overcome the issue of space conflict at the site, the issue of increased inventory costs, issue of communication and coordination with suppliers, as well as issue of quality(Pheng and Chuan, 2001; Kim, 2002;Mahmoud Said, 2010).Therefore, in this current discussion, the determination for using the JIT principles must be decided by considering their appropriately with the real-time situations at the site.At this stage, there are four sub-processes which have to be followed and agreed upon, and they are:

a. Produce construction sequence (A);
b. Identify space needs requirement (B);
c. Produce space layout (C); and
d. Sequence for activity (D).

Every sub-Process is labelled as A, B, C, and D. These labels have the purpose to facilitate the concentration and emphasis during the process of resolving the workspace conflict.Planners only need to focus and take solution measures by referring to certain sub-processes and not on the whole sub-processes.

Sub-Process A: Produce construction sequence:

All inputs regarding component and material information, construction design and construction activity schedule need to be arranged to produce work sequence, component and material delivery, as well as space arrangement order. Work sequence explains that the sub-contractor or workmen are required to work according to sequence either in the building, building level, room and work in stages. The delivery of construction components and materials explains the need to have sufficient number of components and materials for a work activity. It is asserted that the availability of component and materials in the work area, also the locations for storing and positioning must also be emphasised. For space arrangement, aspects like determining workspace use, storing and pathway need to be detailed in graphic.In terms of explaining the information of construction activity scheduling, it directly relates with the dependency on the level of availability and demand for both components and materials for related sub-activities. Space behaviour pattern elaborates on how work element operates or normally done whether in linear, spiral, horizontal, building face, vertical or random form. The determination over the behavioural pattern influences the type of arrangement, sequence, and solution to the space conflict that will be decided in the discussion session.In the meantime, work orientation pattern explains how a work element activity or component is installed on the structure of the building constructed. This pattern covers the installation technique from the top, outside, inside, and also around the connected side.

Sub-process B: Identify space needs requirement:

The scheduling of work activities, components, and materials needed, as well as the project design must be determined with reference to specific workspace types. It is needed for the work activities being focused. The construction activity schedule functions to identify what kind of activities need to be included in the planning.Meanwhile, the aspect of component and materials plays the role to evaluate and decide on the type of construction components and materials also specifically, the total quantity for every activity for each workspace. At the same time, design information is also crucial so as to examine and determine the location of the component and the material's position on the work space. All activities in the work elements are grouped according to the sub-activities. This is to ensure that the work to be completed is assigned by level, work unit or repetition. The activities need to be made consistent with the utilization of space in a specific manner. It will give a better picture on the total space needed for every work element. The process outcome recognises that the requirements of space utilization will be able to determine the following aspects:

a. The list of activities in every work element together with space arrangement and prepared for according to sequence (B1);
b. Specific activity space needed in the work area (B2);
c. The selection of work method determines the location of space. The selection has to consider the aspect of machine workability (for instance, crane machinery-boom movement), machine positioning (including the lorry) in the work space, and the arrangement of temporary facilities at the site that may disturb work processes. As a guideline, this temporary arrangement must be made in such a way that the facilities do not get in the way of the

work activities, that they make work flow easier (component and material, machinery and equipment, also labour) as well as making the work environment safe. For the IBS component storing at the site, the best arrangement method has to be discussed. IBS components like the floor structure and the wall structure necessitate a certain way of arranging to avoid them from damage like broken, and so on (B3);

d. Component and material information for determining the order of the delivery or placement at the location in question. Physical characteristics of the component and materials, characteristics of space and component availability, machinery and labour at the site should be considered. The IBS components and the large-scale and heavy mould are also worthy to be considered. Thus, the contemplation over the space size (whether the storage or location, as well as work space), appropriate type of machinery, and the logistic planning approach JIT-wise must be accounted for accordingly (B4).

e. Space for the component and material, and pathway. It seeks to determine the space needed for movement and support to the work area. The aspect of movement covers the movement for the component and materials, equipment and machinery, workers and constructions wastes. The pathway that needs to be prepared should be the nearest to the operation area and it also has to be safe. The pathway must always be ready and maintained to ensure smooth work process (B5).

Sub-Process C: Produce space layout:

In this process, the workspace behavioural pattern should be identified and stated in specific for every work element selected. The space behavioural pattern gives guidance in terms the location of a specific space and the type of workspace classification either in the building (including in the surrounding area), floor level, and rooms. This sub-process output should be illustrated through the workspace arrangement plan onto the position of the workspace required for the work elements and the distribution of sub-activities for every building, floor level or room. The same applies to the space behavioural pattern set which determines the workers' movement pattern through this pattern of space behaviour.In short, in this sub-process, the planning process works as follows:

a. Preparation of the space behavioural pattern – making decision and selection on the space behavioural pattern based on the work activity attributes, so as to determine characteristics of space utilization requirement. This pattern adopts the linear, random, horizontal, vertical, spiral, and building face. The work orientation pattern also influences the space behavioural pattern like component installation from the top, outside, inside, and also around the connected side (C1).

b. Determining the space arrangement for building level, floor and rooms – making decisions on workspace positions, positioning and storing, pathway also related spaces (C2).

c. Generating space arrangement through the production of graphic space arrangement plan.This is to show in specific the location and the requirement for space use (C3).

Sub-process D: Sequence for activities:

The work activities that are done in sequence and simultaneously have to be done and the sequence of the work units for the completion of the work elements have been identified. The same goes with the aspect of the component delivery and materials arrangement. These activities are divided in four aspects such as:

a. Work according to the building, by determining work in sequence based on logical order and dependency on other activities (D1).

b. Work, according to the floor level by determining the work direction for every activity (for instance, from left to right) (D2).

c. Work, according to the room – based on logical order and dependency among various types of work (D3).

d. According to component and material delivery. The planners must identify the schedule for the component and materials to be sent to the construction site, and are available in the work area, around the building, building level and room space (D4).

Having determined the planning process through the four sub-processes, the planning team should discuss carefully all the suggestions made.Before any decision is made, all aspects with regards to the potential that any interferences and workspace conflicts can happen, must be given due attention.If such a possibility exists, other problems would emerge such as issues stemming from technique selection, work methodology, selection of space behavioural pattern and work orientation, more detailed discussions must focus to only certain sub-processes and not to the entire processes. Otherwise, the next process will entail finalising the decision, preparing the schedule and documenting the decision as an official or a formal plan as construction reference.

Process 4: Implementation of monitoring the planning:

The next process is to implement space planning that has been decided and scheduled by the planning team. In this process, the aspects of communication and coordination among all parties must be very good.Previous findings have come to the issues of communication and coordination with the sub-contractors and IBS component suppliers, which leads to the distraction and conflict of the workspace prevalent in the IBS work environment. These problems will emerge although the workspace planning aspect has been formulated and planned in a realistic way. However, in this planning process, the guidelines in problem-solving are also provided realistically.

Table 3: Types of interference and workspace conflict and its troubleshooting steps.

Types of interference and workspace conflict	Causes	Troubleshooting steps for types of interferences and workspace conflict (must only refer to and focus on related sub-processes)
Congestion in preparation space, placement, and storage of IBS components	▪ Components' size too big	Practising JIT approach
	▪ Lack of space maintenance	Practice regular maintenance
	▪ Components being kept at storage area for too long	D4 – Identify the delivery schedule
	▪ Placement of item at wrong area	B4/C2– Identify component and material's information/ identify placement area
	▪ Early delivery of components by supplier	D4 – Identify delivery schedule
	▪ Wrong components delivered by supplier	B4 – Identify component's information
	▪ Unavailability of crane	B4/Work practice – Identify component's information
	▪ Coordination with supplier	D4 - Identify delivery schedule
	▪ Did not practice JIT	Practising JIT approach
	▪ Unsuitable storage location	C2 – Identify space layout
	▪ Lack of crane	Work practice
	▪ Limited storage space	Practising JIT approach
	▪ Unavailability of storage space	B4 – Identify component's information
	▪ Unavailability of labour	B4/Work practice – Identify component's information
	▪ Unsuitability of component's arrangement technique at sites	B3 – Identify component's arrangement method
	▪ Lack of space maintenance	Managing the construction waste
	▪ Unavailability of workspace	B4/ Work practice – Identify component's information
Congested space at IBS components assembly area	▪ Unavailability of installation handling space	B4/ Work practice – Identify component's information
	▪ Components' size too big	Practising JIT approach
	▪ Machineries are too big	Practising JIT approach /B4 – Identify requirement for machinery usage
	▪ Inefficient technique for component's installation	B3/C1 – Selection of work methods/ identify behaviour of workspace patterns
	▪ Overlapping of works with other activities	D2/D4 – Identify work sequence by level/ Components and materials delivery sequence
	▪ Unavailability of crane	B4/ Work practice – Identify component's information
	▪ Unavailability of worker	B4/ Work practice – Identify component's information
	▪ Damaged components	B3 – Selection of work methods / Identify component arrangement method
	▪ Non-standard design of components	B4 – Identify component's physical attributes
Congestion in non-IBS workspace	▪ Worker working out of sequence	D2/D3 – Identify level and room sequence
	▪ Worker oppress one another	B2/D2 – Identify specific space for activities/ Identify level of sequence
	▪ Working at congested space	Provide ample workspace
	▪ Various sub-contractors operate at the same workspace	D2/D3 – Identify level and room sequence
	▪ Pressure of completion of work	B3/B4 – Identify work types/ Identify component and material's information
	▪ Workers threaten to delay	Delay in activities
	▪ Material stored at work area	C2 – Identify storage layout
	▪ Did not practice JIT	Practising JIT approach
	▪ Correction of work	D – Readjustment of work sequence
	▪ Various craftsmen working at the same area	D2/D3 – Identify level and room sequence
	▪ Irregular construction method	B3 – Selection of work methods
Blockedmaterials and components path	▪ Components stored along the route	D4 – Component delivery sequence/ Practising JIT approach
	▪ Other construction located along the route	C2 – Identify space layout (storage space)
	▪ Unavailability of route	Work practice (maintenance)
	▪ Heavy use of machineries along the same passageway	B3/B4 – Selection of work methods / Component's information
	▪ Component size too big	Practising JIT approach
	▪ Machineries are too big	B3/B4 – Selection of work methods / Component's information

Table 3:*(Continued).*

Types of interferences and workspace conflict	Causes	Troubleshooting steps for types of interferences and workspace conflict (must only refer to and focus on related sub-processes)
Blockedmaterials and components path (Cont'd)	▪ Work carried out along the passageway	D1 – Identify sequence by building
	▪ Workspace obstructing the path	D1 – Identify sequence by building
	▪ Machineries stored along the passageway	B2/B5 – Identify specific space for activities / identify component's space and route
	▪ Limited storage area	Practising JIT approach
	▪ Unavailability of workspace	B4/ Work practice – Identify component's information
	▪ Unsuitable work systems	B3 – Selection of work methods
Interruptions during the process of lifting the materials and IBS components	▪ Bad weather	Specific action to accommodate the plan
	▪ Unavailability of component's installation area	B4/ Work practice – Identify component's information
	▪ Irregular facility layout	B3 – Selection of work methods / temporary facility layout
	▪ Unavailability of crane	B4/ Work practice – Identify component's information
	▪ Disruption due to existing building	B3/C1 – Selection of work methods / identify behaviour of workspace patterns
	▪ Incompetence of crane's operator	Action by the Management
Too much materials at work area	▪ Lack of coordination among craftsmen	C2 – Identify space layout with work position
	▪ Did not practice JIT	Practising JIT approach
	▪ Unavailability of storage space	Work practice
	▪ Weakness in material scheduling plan	B4/ Work practice – Identify component and material's information to determine the sequence of delivery & deployment
	▪ Lack of coordination among craftsmen, suppliers, and sub-contactors	B4/C2/ Work practice – Identify component and material's information to determine the sequence of delivery & deployment / Identify space layout with work position
	▪ Lack of suitable storage space	C2/ Practising JIT approach - Identify space layout with work position
	▪ Construction materials placed around the work area	C2 – Identify space layout with work position
Work out of sequence	▪ Materials restrict the sequence planning	C2/ Practising JIT approach – Identify space layout with work position
	▪ Pressure from out of sequence works	Sequencing problem
	▪ Craftsmen not planned according to sequence	D2/D3 – Identify sequence by level/room
	▪ Construction waste restricts sequencing of storage	Management of construction waste
Damage of IBS components	▪ Error during component preparation process	Work practice and verification of construction design
	▪ Components are damaged at factory and during placement at the site	Work practice
	▪ Components and materials stored for too long	D4 – Identify delivery schedule
	▪ Storage at wrong location	B4/C2– Identify component and material's information / identify placement area
	▪ Did not practice JIT	Practising JIT approach
	▪ Components and materials dropped	Work practice /safety
	▪ Unsuitable storage method	B3 – Selection of work methods / Identify component's arrangement method
	▪ Unsafe work methods	B3/ Work practice (safety) – Selection of work methods
	▪ Weakness in installation handling methods	B3/C1 – Selection of work methods / identify behaviour of workspace patterns
Materials and IBS components located far from work area	▪ Workspace unavailability	B4/ Work practice – Identify component's information
	▪ Error during placement and storage process	B4/C2 – Identify component and material's information to determine the sequence of delivery and deployment / Identify space layout with work position
	▪ Other construction materialsand components located at storage space	C2– Identify space layout with work position
Work in hazardous area	▪ Conflict between two work activities in the same workspace	D2/D3 – Identify sequence by level/room
	▪ Lax security policy	Work practice (safety)

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Table 3:*(Continued).*

Types of interferences and workspace conflict	Causes	Troubleshooting Steps for Types of Interferences and Workspace Conflict (must only refer to and focus on related sub-processes)
Double handling of materials and IBS components	▪ Components delivered too early	D4 – Identify delivery restrictions
	▪ Unorganized flow of components to work area	D4 – Identify delivery restrictions
	▪ Did not practice JIT	Practising JIT approach
	▪ Materials delivered in stages	D4 – Identify delivery restrictions
	▪ Lack of storage space	Practising JIT approach
	▪ Workspace unavailability	B4/ Work practice – Identify component's information
Work damaged and removed work	▪ Error during installation works	Work practice
	▪ Component did not meet specification	Verification of construction design
	▪ Damaged components	Work practice
	▪ Objects dropped	Work practice /Safety management
	▪ Error in material usage estimation	Work practice
Debris build-up in the work area	▪ No construction waste removal procedures	Construction Waste Management
	▪ Not according to the procedures set	Construction Waste Management (action)
	▪ Less suitable work methods	B3 – Identify suitable work methods
Accidents from falling objects	▪ Less emphasize on safety aspects	Work practice (safety)
Injury from hazardous	▪ Less emphasize on safety aspects	Work practice (safety)
	▪ Workers fell off from building	B3 – Identify workspace, hazard space and work practice
	▪ Negligence and safety flaws	Work practice (safety)
Unavailability of in-building path	▪ Inefficient work methods	B3 – Identify suitable work methods
	▪ Pressure due to completion of work	B5 – Identify passageways and support routes to the work area
Unavailability of workers' path	▪ Worker's lifts are not provided	B5 – Identify workers' passage (vertical path)

Process 5: Workspace conflict resolution:

Types and causes of interference need to be assessed first before any action to solve workspace conflict is taken and decided. Identification of space overlapping in different activities of the work element must be properly observed. Results of the discussion on interference problem solving steps are referred in deciding the following actions:

a. Readjusting the aspect of work sequence; or
b. Customizing all work layout aspects; or
c. Re-attune all aspect of methods of work.

However, these troubleshooting actions depend on interference types and causes, as well as the behaviour of workspace patterns. Therefore, specific troubleshooting action needs to be taken by referring to Process 3. Table 3 presents the example of troubleshooting process for interferences and workspace conflict based on its types and causes.

During the fourth stage of planning, implementation and monitoring of the plan, if there is no workspace disruption and conflict detected, then the workspace planning process can be considered as complete. Therefore, the space planning cycle for new work elements can be re-established, beginning with information gathering process (Process 2) (refer Figure 1 – Flow chart of model for workspace planning process).

Results:

Nine panels of experts from various fields were selected to evaluate the content for this model for workspace planning process. Respondents' demographic analysis is presented in Table 4 below.

Table 4: Demographic profile of respondents.

Demographic	Frequency	Percentage
Position		
Academician	3	33.3
Firm manager	1	11.1
Project manager	3	33.3
Project planner	1	11.1
Others	1	11.1
Key areas		
Teaching and research	3	33.3
Construction practice	4	44.4
Construction administrator (government agencies)	2	22.2
Experience in key areas		
10 years - 15 years	1	11.1
>15 years - 20 years	3	33.3

>20 years	5	55.6

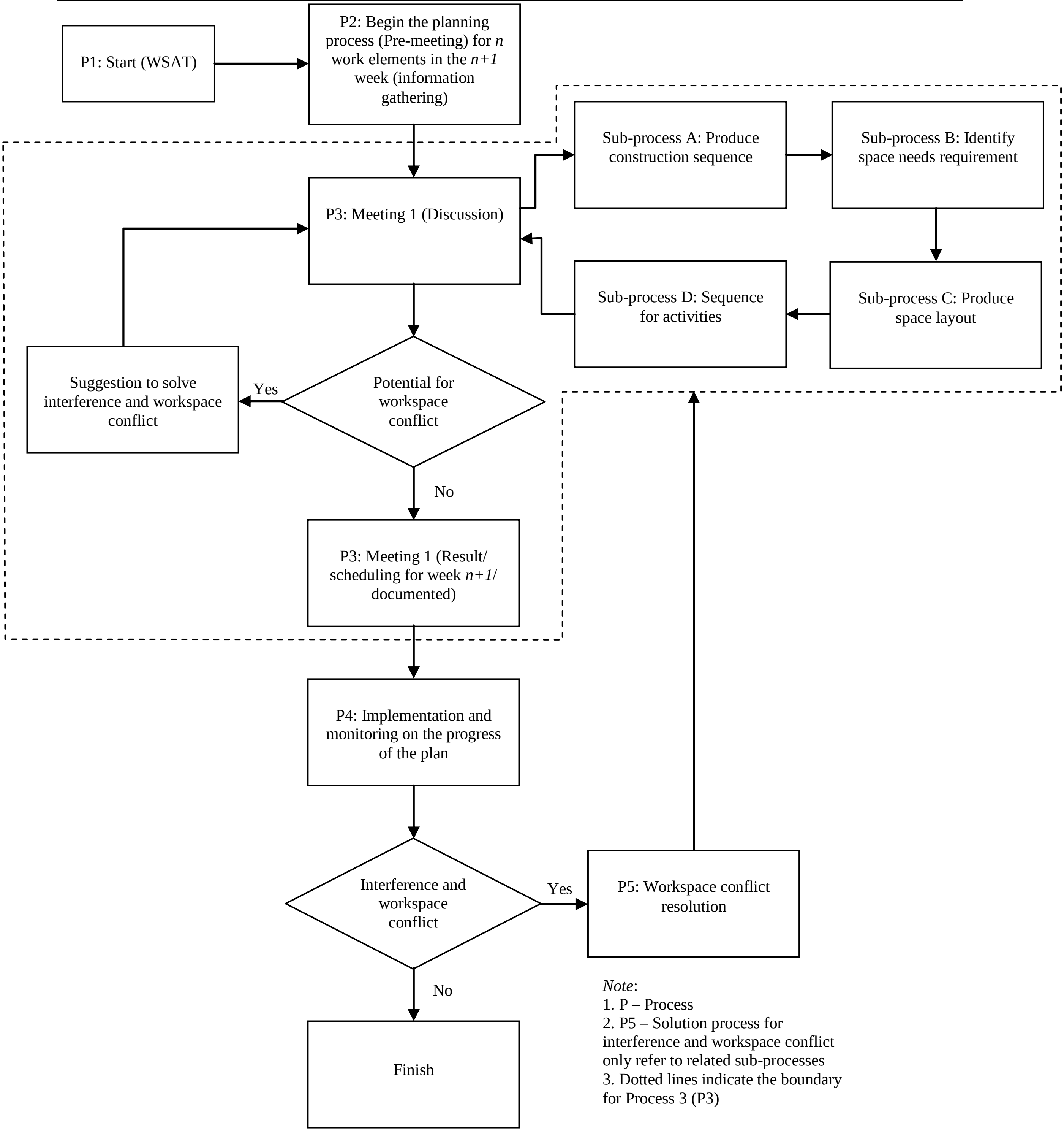

Fig. 1: Flow chart of model for workspace planning process.

A total of 15 questionnaire items were employed in this evaluation using the Likert scale. Based on these 15 questionnaire items evaluated by the respondents, they generally agreed with the model for workspace planning process designed. This shows that respondents were satisfied with the developed model and they agreed that this model could give positive impacts on IBS construction environment (Table 5). Observing the questionnaire item which refers to the aspect of systematic clarity of workspace planning processes, it was found that 55.6% or five respondents agreed with the statement. On the other hand 44.4% or four respondents gave “strongly agree” respond. This illustrates that this model has been systematically developed for each process involved in planning. For the statement “Steps in each process are clearly described in detail”, very positive feedbacks were received. Six of the respondents or 66.7% strongly agreed. In addition, three respondent or 33.3% agreed with the statement. Each single process in this model is described in detail so that it can be easily referred by the planning team and then aspects that need to be emphasized can be discussed. The prepared flow chart for these processes serves as a guideline to the planning team so that they can follow each step of the process more easily. For questionnaire item concerning “The process steps are realistic, and can be implemented”, analysis showed that two respondents (22.2%) gave neutral feedback, 33.3% whilst three respondents agreed. Besides that, four respondents or 44.4% strongly agreed with the item. In general, seven out of nine respondents gave positive respond on this item. This shows that each planning process can be logically and realistically implemented. The next item which evaluate the aspect of solution towards workspace disruption and conflict, it was found that six respondents (66.7%) agreed whilst another three (33.3%) strongly agreed. Suggestions to solve workspace disruption and conflict were prepared by considering the types of disruption and conflict that really happen at construction sites for IBS project. Therefore, planning team already had an early impression on workspace disruption and conflict commonly occurred in the environment of IBS projects. Furthermore, the proposed solution prepared in this model requires the planning team to only focus on specific issues and specific solutions only.

Table 5: Evaluation on the content of model for workspace planning process by experts.

Items	Frequency and Percentage*				
	1	2	3	4	5
Systematic clarity about the planning processes	0	0	0	5 (55.6)	4 (44.4)
Steps in each process are clearly described in detail	0	0	0	3 (33.3)	6 (66.7)
The process steps are realistic, and can be implemented	0	0	2 (22.2)	3 (33.3)	4 (44.4)
Suggested solutions on workspace disruption and conflict are realistic, and can be implemented	0	0	0	6 (66.7)	3 (33.3)
Forms communication and coordination network between various parties involved in preparation and implementation	0	0	0	5 (55.6)	4 (44.4)
Provides clear information on work methods, scheduling of activities, space usage, space layout, chain of sequence, and solution for interference and workspace conflict	0	0	0	6 (66.7)	3 (33.3)
A realistic model in assisting the optimization of the planning of space utilization, and other, as well as planning of onsite works	0	0	1 (11.1)	3 (33.3)	5 (55.6)
The suitability for this model to be implemented in short term planning	0	0	2 (22.2)	4 (44.4)	3 (33.3)
The importance and suitability for this model to be implemented in the environment of IBS projects	0	0	0	4 (44.4)	5 (55.6)
Able to reduce interference and workspace conflict at construction sites	0	0	2 (22.2)	2 (22.2)	5 (55.6)
Able to improve quality, constructability, safety, and productivity	0	0	2 (22.2)	3 (33.3)	4 (44.4)
Able to add value and provide enhancement in workspace planning process at job sites	0	0	1 (11.1)	5 (55.6)	3 (33.3)
A technique that is able to support strategic decisions in the aspect of workspace planning	0	0	2 (22.2)	4 (44.4)	3 (33.3)
Has the potential to benefit the contractor	0	0	0	3 (33.3)	6 (66.7)
Can be applied to actual construction situation	0	0	2 (22.2)	3 (33.3)	4 (44.4)

Note*: 1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree, and 5= Strongly Agree

The next analysis focuses on how the developed model is able to form communication and coordination network between various parties involved in preparation and implementation. Five respondents or 55.6% agreed whilst another four or 44.4% strongly agreed with the item. This workspace planning model requires integration of all parties involved. Eight parties involved in this planning process had their own functions and roles. In fact, advantages and expertise from various members can lead to a collaboration that is able to produce effective workspace planning. Next, focusing on the aspect of information and planning, around 66.7% or six respondents agreed whilst another 33.3% strongly agreed. The preparation of this planning model takes into account the aspect of work methods, scheduling of activities, usage of space, space layout, chain of sequence, and the process of solving workspace disruption and conflict. The model is seen to be more thorough because all aspects have been considered and given attention. Each member of the planning team is able to find out information about the project, work methods, project restrictions, and steps to overcome workspace disruption and conflict extensively. Hence, it simplifies the process of discussions and decisions that must be made. The next analysis deals with the ability of this model to optimize use of resources and work planning on job sites. Five respondents or 55.6% strongly agreed whilst 33.3% or three respondents agreed. Only 11.1% or one respondent gave neutral respond. Positive feedbacks received from the majority of the respondents reflect that the development of this model does consider the aspect of the need of various resources such as space, tools and machineries, materials and components, and labour resources. The need for these sources is described in detail thus facilitating the planning process by the planning team.

This model is specifically designed for short-term planning. Therefore, the next questionnaire item focuses on the appropriateness of this model to be applied for short-term period. Overall, only two respondents, or 22.2% gave neutral feedback whilst three agreed and another 33.3% or three respondents strongly agreed. In brief, this model can be applied for short-term planning. Justification for this finding can be understood by observing the nature of construction activities that involve various building elements such as different types of component, component's size, labour, tools and machineries, building design, and different work methods. Workspace disruptions and conflicts that could possibly occur are different. Therefore, short term planning is more appropriate in providing a specific approach which can serve as guideline according to the work elements. This model is developed for the purpose of workspace planning for the environment of IBS projects. Thus, the next questionnaire item focuses on the importance and suitability for this model to be implemented in the environment of IBS projects. Data analysis further shows that positive feedbacks were received by all respondents. Four respondents agreed whilst the remaining five or 55.6% strongly agreed. The application of IBS in projects in Malaysia is still not comprehensive. Conventional methods are still needed especially for the architectural and aesthetic works. The workspace planning approach in this model also takes into account the conventional methods. Therefore, although this model is classified for IBS projects, conventional methods are still given emphasize.

Data analysis for the item "Able to reduce workspace disruption and conflict at construction sites" showed that two respondents gave neutral feedback, another two agreed whilst five respondents (55.6%) strongly agreed. Overall, the feedbacks showed that this model is expected to be able to provide solutions towards problems concerning space issues. Therefore, with this preparation of workspace planning, the planning team which is headed by the project manager has clearer and systematic planning guidelines. For this to work, this model must be extensively practiced, by following the sequence of processes. In addition, there are two stages of workspace disruption and conflict troubleshooting prepared in this model to assist the planning team in discussing and determining the most reasonable decision to address the issue of workspace disruption and conflict at the construction sites. The next analysis focuses on the ability of this model to improve quality, constructability, safety, and productivity. The pattern of feedbacks received is found to be almost identical with previous item. Two respondents (22.2%) were neutral, three (33.3%) agreed and another four (44.4%) strongly agreed. On the average, the feedbacks received were positive. The methodology of this model is developed in an orderly and detailed manner. It is quite impossible to get negative results in work processes at job sites if all parties played their roles and responsibilities. At least this model gives appropriate guidance in creating a more efficient construction process by adopting workspace planning in modern construction practice in Malaysia.

Data analysis for the item "Able to add value and provide enhancement in workspace planning process at job sites", it was found that only one respondent gave neutral feedback. Five respondents or 55.6% agreed whilst another 33.3% strongly agreed. These positive feedbacks are significantly related to the finding of data analysis on the workspace planning technique practiced by contractors. So far, the contractors did not have a detailed and specific workspace planning. With the availability of this model, it can guide the contractors on the need and requirement for workspace planning, especially the use of IBS method in most projects in Malaysia that require initiative and innovation in workspace planning at construction sites. Moving on to data analysis on item "A technique that is able to support strategic decisions in the aspect of workspace planning", there were two respondents (22.2%) who gave neutral feedback whilst four or 44.4% of the respondents agreed and the remaining 33.3% strongly agreed. Any decision made requires justification, reference, guide, and democratic opinion or consensus. Therefore, this model provides an approach which centred on discussion among various parties based on aspects mentioned earlier. The development of this model is able to provide an alternative to the planning team in preparing the best workspace planning to create a more positive construction environment. All respondents indicated that the model developed has the potential to benefit the contractor. Three respondents or 33.3% agreed whilst another six or 66.7% strongly agreed with this statement. This model provides a new technique for contractors in improving quality, productivity, safety, and work constructability. Therefore, this model is able to directly produce positive impact for contractors in carrying out works at the construction sites. Analysis of the final item "Can be applied to actual construction situation", it was found that only two respondents or 22.2% gave neutral response. Three respondents or 33.3% agreed with the statement whilst the remaining four respondents or 44.4% strongly agreed. This model is only evaluated in terms of its effectiveness based on the contents prepared. Nevertheless, positive responses from experts indicate that this model has the potential to be effectively implemented in real construction environment.

With regards to the open ended questionnaire item, namely the comments and suggestions section, there were some suggestions given by respondents which aimed to improve the suitability of this model. Three respondents gave such feedbacks. They suggested that appropriate forms for each workspace planning processes are provided, so that any decision made can be easily recorded which could serve as reference during the actual implementation process at construction sites. In addition to that suggestion, it was also suggested that this model is most appropriately implemented at the early stage of construction. This suggestion points to the preparation of a detailed workspace planning to facilitate macro planning, which is the layout of the facilities at the construction site. Next are comments made by construction administrators (project managers). These experts suggested that the sub-planning processes in section A is taken out from the troubleshooting process for interference and workspace conflict (due to the fact that Process A only described the process of the activity and did not refer to the interference and workspace conflict). The second suggestion was about the naming of the model, where it should also reflects that conventional construction methods are also taken into account in the workspace planning. This is to show that the model is flexible and can be applied in both conventional or IBS construction environments.

Conclusion:

Model for workspace planning process is developed given that contractors do not have workspace planning technique at construction sites especially for IBS based constructions. The lack of reasonable and detailed workspace planning could negatively impact them due to the occurrence of interference and workspace conflict. Among negative impacts which commonly persist when this problem exists are reduction of productivity, constructability, safety issues, and delay in project completion. This model for workspace planning process considers a collective approach of preparation of planning represented by team members who are actively responsible at construction sites. Besides that, this model was also developed based on inputs obtained from the results of quantitative and qualitative analysis. In this model, the concept of model development and model for workspace planning process are specifically described. As for the planning process, it consists of five processes developed by taking into account the micro space, macro space, and passageway aspects, as well as interference and workspace conflict solving methods. The analysis conducted on the contents of this model shows that positive feedbacks were received from all panels. This indicates that the contents of this model are able to provide a detailed and thorough workspace planning that is applicable in the real IBS construction environment.

Limitation of the Research:

Model for workspace planning process developed in this study has yet to be tested in any real IBS construction environment. Time constraints and the lack of IBS projects in the current construction process had restricted the model from being tested, thus further research is required.

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