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Building Condition Assessment for New Houses: A Case Study in Terrace Houses

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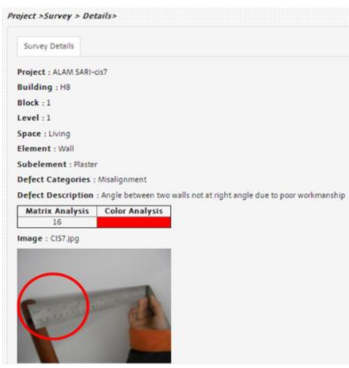
Graphical abstract



Abstract

This study determines the types of defects often detected in residential buildings based on the criteria set by the Construction Industry Standard (CIS) 7: 2006–Quality Assessment System for Building Construction Work. Twenty-two terraced two-story houses located in Selangor, Malaysia were visually inspected and assessed in terms of building condition, and results were reported based on the Condition Survey Protocol 1 Matrix. Assessment findings were consolidated with those of defective groups based on the criteria of CIS 7: 2006 to determine the defect type, building component, and construction field in which defects often occur. Results show that most of the inspected houses are dilapidated even though they were recently completed. The most severe building defects are detected in the architecture. Furthermore, floors and walls are major contributors to building defects. Mainly as a result of poor workmanship, the most common defects involve finishing, alignment and evenness, and joint and gap. Thus, this study proposes a method to ensure high-quality workmanship.

Keywords: Condition survey; building inspection; CSP 1 Matrix; CIS 7: 2006; QLASSIC; building defects in Malaysia

Abstrak

Kajian ini menentukan jenis-jenis kecacatan yang biasa ditemui pada bangunan kediaman berdasarkan kriteria yang ditentukan dalam Construction Industry Standard (CIS) 7: 2006–Quality Assessment System for Building Construction Work. Sebanyak 22 buah rumah teres dua tingkat yang terletak di Selangor, Malaysia diperiksa secara visual dan laporan keadaan bangunan dibuat berdasarkan Matriks CSP1. Penemuan pemeriksaan dibandingkan dengan kriteria CIS:7 bagi menentukan jenis kecacatan, komponen bangunan, dan bidang pembinaan yang sering berlaku kecacatan. Keputusan menunjukkan keadaan hampir semua bangunan yang diperiksa adalah usang walaupun baru siap dibina. Bidang yang paling terjejas adalah Seni Bina manakala lantai dan dinding adalah penyumbang terbesar kepada kecacatan bangunan. Disebabkan mutu kerja yang lemah, kecacatan yang tertinggi adalah melibatkan kemasan, penjajaran dan kerataan, dan sambungan dan jurang. Maka, kajian ini mencadangkan kaedah untuk memastikan kualiti mutu kerja adalah baik.

Kata kunci: Pemeriksaan keadaan; pemeriksaan bangunan; Matriks CSP1; CIS:7 2006; QLASSIC; kecacatan bangunan di Malaysia

■1.0 INTRODUCTION

Given the high demand for housing, the industry of residential building construction is developing rapidly. This development is beneficial for developing countries because it fulfills the basic human need for shelter. Despite the quick progress of the industry, however, the quality of constructed residential buildings is poor, especially that of recently completed houses.[1] Poor construction quality means that project objective cannot be accomplished, does not meet customers' need and does not meet the specification.[1]

The result of survey by Zamharira *et al*. (2012) demonstrated that customers' satisfaction affect by construction work and building material.[2] Therefore, construction quality must be evaluated to ensure that houses meet the specified requirements. This assessment not only protects buyer interests, but also improves the workmanship quality of developers and contractors.

In response to this situation, the government of Malaysia has established numerous Construction Industry Standards (CIS) through the Construction Industry Development Board (CIDB), including a quality assessment system for construction works. This system is known as the Quality Assessment System for Building Construction Work (QLASSIC) and guides the evaluation of the quality of construction works in Malaysia.

QLASSIC is the system used for assessing the quality of the finished construction product. Therefore, there are limitations to asses any design defect and failure. Thus, the assessment focus on workmanship quality, not design quality. Based on the criteria of CIS 7: 2006, this study assesses the condition of double-story terrace houses, especially in term of workmanship quality.

■2.0 LITERATURE REVIEW

The construction industry is the engine of economic development in the country and affects several industries, such as manufacturing, finance, and education.[3] This statement supported by Solis-Carcano and Arcudia-Abad (2013) stating that construction activities contribute significantly in the national economy and provides a wide range of jobs.[4] The construction industry is divided into four main categories, namely, landed and stratified housing and public and special public buildings.[5] Housing provision stabilizes the society and the economy of all countries.[6]

In Malaysia, housing construction is initiated by the government and by private property developers. The government has launch affordable housing programs to help the people to own their own homes. However, this programs affected by the existence of a report on quality problems and defects.[7] In Spain, the quality of residential construction problems is due to inexperienced workers and long chain of sub-contractors.[8]

In the construction industry, failures and defects are common.[9] The number of defective houses has recently increased in Malaysia, where people renovate their homes to enhance property value and increase space for living comfort.[10] Ahmad *et al*. (2011) reported that 30% of their study respondents are dissatisfied with the sizes of their kitchens, with extra land, and with humidity.[10] Therefore, most home buyers are discontent with their homes despite the high price paid. The quality of housing provision is important because it is associated with the quality of life of residents. [10,11,12] Hence, buyer interests must be protected.

Building defects may include any problem that reduces the value of a property, including houses.[9] Josephon and Hammarlund (1999) state that a defective construction processes may influence building defects at either the operational or maintenance stages.[13] Other factors that may lead to building defects and failures are design errors by the architect, manufacturing flaws, defective materials, the improper use or installation of materials, deviation from the design by the contractor, or a combination of these factors. Climate conditions, building location, construction materials, building type and change in usage, building maintenance, faulty design, corruption, and lack of supervision also contribute to defects and failures.[9] Besides, analysis conducted by Love *et al*. (2014) showed that the average cost of design errors is 14.2% of the original value of the contract.[14]

There are many problems that affect the quality of construction projects such as standard reduction, increased cost, projects delay, unskilled workers and less qualified construction technologists.[1] Besides, some physical aspects affect building quality, including design, size, the material used, and the finishing of the houses.[15] Other factors that worsen construction quality are the poor specification of materials, workmanship, and quality of technical elements and services.[16] Mohd Zaki (2006) determined that some defects are induced by design and construction errors, as well as building misuse.[17] According to Ramly (2004), the five main factors in structural defects in concrete are building material, geo-technique, and design, construction, and unpredicted errors.[18] However, the main factor that contributes to poor workmanship is lack experience and competency of labors.[3]

The most common building defect and failure is blemish.[9] Blemishes in concrete come in the form of scaling, honeycomb, air pockets, and bolt holes. These blemishes are caused by unskilled workers, lack of supervision, and rushed construction. Thus, construction materials and poor workmanship are the main contributing factors to building defects and failures. Most defects identified by the buyer after handover due to poor work quality and related to construction errors and missing.[8]

Building qualities are also related to safety.[19] Yau (2006) confirmed that safety is a quality factor.[20] Moreover, Husin *et al*. (2011) conclude that the safety of a building is strongly associated with building quality because the occupants are endangered if the construction quality does not meet standards.[16]

To ensure that households are satisfied with the provided housing and the relevant services, Varady and Carrozza (2000) pointed out that the measurement of housing quality is important.[21] In both the UK and USA, local governments conduct regular surveys of tenant satisfaction surveys. Housing assessment not only protects the interests of home buyers and guarantees safety, but it also collects feedback on current projects and feed forward for future projects.[22]

Most of the defects in residential buildings are induced by poor workmanship, which is closely related to developers and contractors.[8] Thus, assessing the satisfactions of home buyers are necessary.[23] Prior to turnover, home buyers in Malaysia typically inspect the house. However, most home buyers are technically unschooled on building defects.[6] As a result; they overlook some of these defects. Therefore, buyers must be accompanied by a professional surveyor during inspection.

The assessment of building condition is a technical inspection conducted by a competent assessor to evaluate the physical state of building elements and services and to determine the maintenance needs of the facility.[24] A professional building surveyor can examine building conditions comprehensively, and the generated detailed report can protect the interests of new home buyers, especially with respect to technical aspects such as workmanship and material. Moreover, property developers can consider this report in managing building defects.[6]

Building and facilities management activities such as planning, implementation and maintenance are important criteria in ensuring the sustainability of buildings can be achieved.[25] They classified the maintenance activities into two types such as scheduled maintenance and condition-based maintenance. However, both approach required building inspection to assess the condition of building before taking further action. Information obtained from the building inspection used to make decisions about repair work.[26]

Thus, the assessment of building condition is important in evaluating building quality. To indicate building quality, assessed buildings must be rated. A rating is a set of categorization scales designed to expound on the quantitative or qualitative attributes of an object.[27] Using a standard, a building inspector can evaluate the status of the building objectively for a property manager.[28] The CIDB has therefore introduced a system called QLASSIC to measure construction quality and evaluate workmanship quality in Malaysia. The quality standards of building construction consist of four main components, namely, structural, architectural, mechanical and electrical (M&E), and external works. However, only the architecture, M&E fittings, and external works are considered in the assessment of building construction quality in completed projects. Through this system, all defects have been categorized into specific groups.

■3.0 METHODS

In this research, 22 recently completed terrace houses in Selangor, Malaysia are surveyed in terms of building condition. All 22 houses were built under the same development phase, same set of contractor and consultant. The selection of the houses to make sure that all the factors that may be affect the construction quality can be controlled. The surveys are conducted using protocol 1 (visual inspection) techniques without destructive testing, and the buildings are inspected based on the criteria of CIS 7: 2006 (QLASSIC) for recently completed buildings.

3.1 Building Condition Survey (Protocol 1)

CSP1 Matrix system has been used as the assessment tool because it provides numerical analysis in determining overall building condition. The statistical result from the analysis is helpful to interpret all data from the survey. The statistic also used to classify the overall building condition.

First, external building conditions are surveyed, followed by internal inspection. Houses are generally inspected in descending order starting from the roof. In this research, however, the roof is inspected from outside the building because of limited access and as a safety precaution. Therefore, internal inspection begins at the first floor.

This study follows the above mentioned inspection rules because external defects may affect the interior of the house. Similarly, defects at the top level of the house may influence the lower levels. These inspection rules therefore simplify the determination of possible causes of internal defects.

Building spaces are composed of three main parts, namely, the ceiling, wall, and floor. Doors and windows comprise the wall, although they are regarded as special components because they possess unique characteristics and are made of different materials. Each space is then inspected from the top down. For example, the ceiling of a master bedroom is first examined, followed by the walls and the floor. All detected defects are captured by a camera and tagged on the building plan. To facilitate referral and the structured and systematic tagging of defects on the plan, space inspection is conducted either in the clockwise or counterclockwise direction, and this sequence must be consistent for each house.

3.2 CIS 7: 2006 (QLASSIC)

To assess the workmanship quality of building projects, QLASSIC was developed as an independent method based on the CIS 7: 2006 standard. It is a standard Malaysian quality assessment. QLASSIC aims to benchmark the quality of the work produced by the Malaysian construction industry, to evaluate the workmanship quality of building projects according to a standard system of quality assessment, to assess the workmanship quality of a building project based on approved standards, to evaluate contractor performance based on workmanship quality, and to obtain data for statistical analysis.

Standards of building construction quality are divided into four main categories, namely, structural, architectural, M&E, and external works. However, only the architecture, M&E fittings, and external works are considered in the quality assessment of completed construction projects. Each category corresponds to several groups of defects based on its characteristics.[5]

As per CIS 7: 2006, these groups of defects should be aligned using the Condition Survey Protocol (CSP) 1 Matrix as reconfigured by researchers (as provided in the Results and discussion section). The criteria from the CIS 7: 2006 standard can then be used to analyze the CSP 1 Matrix inspection results, which are arranged according to defect group. Based on these data, the most common defects can be determined.

3.3 Data Analysis

This stage is important because defect patterns in recently completed houses can be identified. First, the defects detected in each house are determined and categorized according to the construction areas specified in the CIS 7: 2006 standard. Important information regarding these defects includes the number of defects in each area, defect type, and the percentage of defectiveness. After analysis, all of the recorded defects are grouped based on defect type.

■4.0 RESULT AND DISCUSSION

This section discusses the results of house analysis in this study, including overall findings, the results generated according to construction field, and the findings as categorized based on defect group. Figure 1 show defect an example of defect analysis by using CSP1 Matrix system.

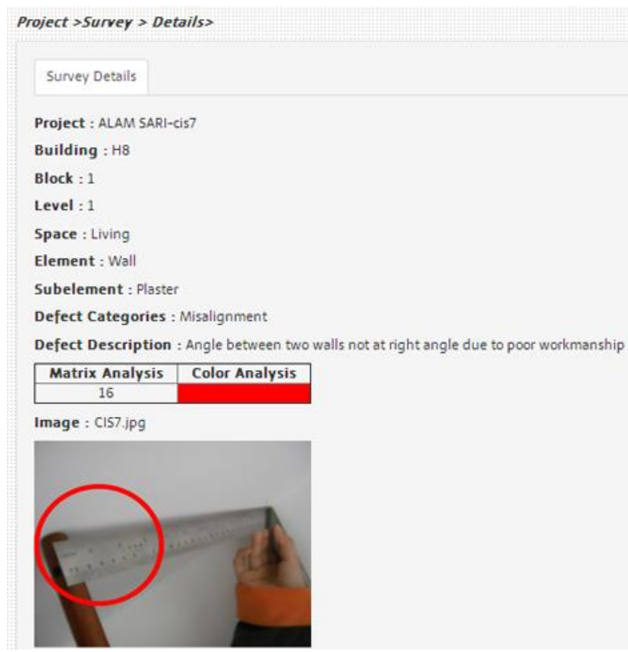


Figure 1 Defect analysis by using CSP1 Matrix system

4.1 Overall Results

Overall, there are 377 defect found in the 22 inspected houses. CSP1 Matrix for each houses were determined and presented in Figure 1. Based on Figure 2, the majority 18 of the houses rated at Dilapidated Condition (Red color). Meanwhile two of the houses are at Good Condition (Green Color) and other two houses were at Fair Condition (Yellow Color). This shows that the quality of workmanship in this development phase is poor.

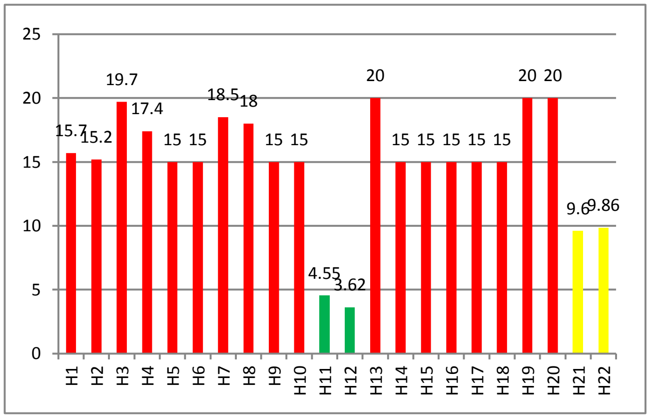


Figure 2 CSP1 Matrix rating for each houses

Table 1 shows the number of defects in the 22 inspected houses. These defects are categorized under architecture, M&E fittings, and external works. The table also indicates that H09 had the most defects at 37, whereas H05 and H06 were the least defective at four defects each. The average number of defects in each house is 17.14. These findings are discussed in detail in the next section.

Table 1 Number of defects in each house

House No.	Number of Defects	House No.	Number of Defects
H01	7	H12	34
H02	24	H13	25
H03	13	H14	19
H04	27	H15	18
H05	4	H16	17
H06	4	H17	12
H07	13	H18	13
H08	10	H19	5
H09	37	H20	9
H10	31	H21	10
H11	20	H22	14
Total Number of Defects		**377**	

4.2 Results Based on Construction Field

According to the analysis, the 377 recorded defects are related to three construction fields, namely, architecture, M&E fittings, and external works. Table 2 lists the number of defects according to these fields.

Table 2 Number of defects based on construction fields

No.	Fields	No. of defects	Percentage (%)
1	Architecture	325	86.21
2	M&E fittings	18	4.77
3	External works	34	9.02
	Total	377	100

As indicated in this table, the majority of defects is associated with architecture at 86.21%. M&E fittings and external works constitute 4.77% and 9.02% of overall defects, respectively. This result suggests that in terms of the number of defects, architecture is dominant over M&E fittings and external works.

4.2.1 Architecture

The field of architectural works has four main components, namely, floor and wall (internal and external), ceiling, door and window, and roof. A total of 325 defects are recorded for this field, and Table 3 distributes these defects according to architectural components.

Table 3 Distribution of defects according to architectural components

No.	Components	No. of defects	Percentage (%)
1	Floor and wall (internal/external)	207	63.69
2	Ceiling	25	7.69
3	Door and window	86	26.46
4	Roof	7	2.15
	Total	325	100

As presented in this table, the component of floor and wall has the most defects at 63.69%, followed by the component of door and window at 26.46%, ceiling at 7.69%, and roof at 2.15%. This result suggests that the floor and the wall are prone to defects. The probability of defectiveness is also higher for doors and windows than for the ceiling and the roof.

a) Floor and Walls (Internal/ External)

In the architecture field, the floor and the wall incurred a total of 207 defects. These defects are categorized into five groups, namely, finishing, alignment and evenness, crack and damage, hollowness and delamination, and joint and gap. Table 4 shows the number of defects in each group.

Table 4 Number of defects in each group (architecture—floor and wall)

No.	Defect group	No. of defects	Percentage (%)
1	Finishing	61	29.47
2	Alignment and evenness	49	23.67
3	Crack and damage	17	8.21
4	Hollowness and delamination	42	20.29
5	Joint and gap	38	18.36
	Total	207	100

Table 4 shows that most of the defects are categorized under the finishing group at 29.47%, followed by alignment and evenness at 23.67%, hollowness and delamination at 20.29%, joint and gap at 18.36%, and crack and damage at 8.21%. These percentages suggest that most of the groups differ only slightly from one another, with the exception of the crack and damage group. These four groups are strongly related to workmanship quality, whereas defects associated with crack and damage surface gradually as a result of poor workmanship or materials, especially in concrete structures. Thus, this group is associated with the smallest number of defects.

b) Ceiling

The ceiling component is associated with a total of 25 defects, which are divided into five defect groups , that is, finishing, alignment and evenness, crack and damage, roughness, and joint and gap. Table 5 lists the number of defects in each group.

Table 5 Number of defects in each group (architecture–ceiling)

No.	Defect group	No. of defects	Percentage (%)
1	Finishing	2	8.00
2	Alignment and evenness	3	12.00
3	Crack and damage	18	72.00
4	Roughness	0	0.00
5	Joint and gap	2	8.00
	Total	25	100

As exhibited in this table, the crack and damage group has the highest percentage of defects at 72%, followed by alignment and evenness at 12%, and the groups of finishing and joint and gap at 8% each. For the roughness group, no defects were recorded. The crack and damage group varies significantly from the other groups in terms of percentage of defects because defects in the first floor damaged the ceiling of the ground floor. As discussed above, the number of defects in the floor is high.

c) Door and Windows

The door and window component reports a total of 86 defects that are split into five defect groups, namely, joint and gap, alignment and evenness, material and damage, functionality, and accessory defects. Table 6 distributes these defects based on defect groups.

Table 6 Number of defects in each group (architecture–door and window)

No.	Defect group	No. of defects	Percentage (%)
1	Joint and gap	12	13.95
2	Alignment and evenness	10	11.63
3	Material and damage	29	33.72
4	Functionality	34	39.53
5	Accessory defects	1	1.16
	Total	86	100

The majority of the defects is related to functionality at 39.53%, followed by material and damage at 33.72%, joint and gap at 13.95%, alignment and evenness at 11.63%, and accessory defects at 1.16%. The groups of functionality and material and damage are the dominant defect groups given the low quality of the materials used to construct these components. Many of the constructed doors and windows are difficult to open or close, and some components are not functional as a result of damage.

d) Roof

At a total of seven, the number of defects related to the roof is the lowest among those related to all of the components. These defects are divided into five defect groups as shown in Table 7.

Table 7 Number of defects in each group (architecture–roof)

No.	Defect group	No. of defects	Percentage (%)
1	Finishing	5	71.43
2	Roughness, unevenness, and falls	0	0.00
3	Crack and damage	2	28.57
4	Joint, sealant content, and alignment	0	0.00
5	Chockage and ponding	0	0.00
	Total	7	100

As presented in this table, defects were associated with only two groups, namely, finishing at 71.43% and crack and damage at 28.57%. This result may be attributed mainly to the accessibility factor. The examiner inspects only the areas that can be accessed safely. Thus, the roofs cannot be examined comprehensively.

4.2.2 Defects in M&E Fitting

A total of 18 defects are related to M&E fitting, which corresponds to the lowest percentage of defects in this field at 4.77% of total defects. These defects are categorized into seven defect groups as depicted in Table 8.

Table 8 Number of defects in each group (M&E fittings)

No.	Defect group	No. of defects	Percentage (%)
1	Joint and gap	1	5.56
2	Alignment and evenness	1	5.56
3	Material and damage	6	33.33
4	Functionality	2	11.11
5	Accessory defects	5	27.78
6	Accessibility	0	0.00
7	Safety	3	16.67
	Total	18	100

This table indicates that the material and damage group is linked to the most defects at 33.33%, followed by accessory defects at 27.78%, safety at 16.67%, functionality at 11.11%, and the groups of joint and gap and alignment and evenness at 5.56% each. No defects are related to the accessibility group. M&E fittings records the smallest number of defects because the fittings alone are inspected and not the overall construction work on M&E, as suggested in the CIS 7 assessment system for completed houses.

4.2.3 Defects in External Works

External works covers the external fixtures within the gated area of a home and the area outside the building. It is split into 10 defect groups, as displayed in Table 9. This field is related to a total of 34 defects, which corresponds to 9.02% of the total defects.

Table 9 Number of defects for each group (external works)

No.	Defect group	No. of defects	Percentage (%)
1	Finishing	11	32.35
2	Alignment and evenness	2	5.88
3	Crack and damage	8	23.53
4	Hollowness and delamination	1	2.94
5	Joints and gap	6	17.65
6	Functionality	2	5.88
7	Material and damage	2	5.88
8	Accessory defects	2	5.88
9	Chockage and ponding	0	0.00
10	Construction	0	0.00
	Total	34	100

As exhibited in this table, the finishing group has the highest percentage of defects at 32.35%, followed by crack and damage at 23.5%, joint and gap at 17.65%, and the groups of alignment and evenness, functionality, material and damage, accessory defects, and hollowness and delamination at 2.94% each. The groups of chockage and ponding and construction are not associated with any defects.

4.3 Discussion

Based on the inspection results, defects are linked to a total of nine defect groups in the fields of construction and components. Table 10 presents the overall results according to defect groups.

Table 10 Number of defects according to defect groups

No.	Defect group	No. of defects	Percentage (%)
1	Finishing	79	20.95
2	Alignment and evenness	65	17.24
3	Crack and damage	45	11.94
4	Hollowness and delamination	43	11.41
5	Joint and gap	59	15.65
6	Material and damage	37	9.81
7	Accessory defects	8	2.12
8	Functionality	38	10.08
9	Safety	3	0.80
	Total	377	100

As per this table, the majority of defects are related to finishing at 20.95%, followed by alignment and evenness at 17.24%, and joint and gap at 15.65%. This result suggests that the groups of finishing, alignment and evenness, and joint and gap are prone to defects. These defect types are highly correlated with workmanship quality, and most of the defects do not affect the houses structurally. The safety group is associated with only 0.80% of defects. This result corresponding with Forcada *et al*. (2013) stating that the common defects found are improper installation, appearance defects, and missing items or tasks mainly concerned with finishing.[8]

Based on these findings, work quality should be improved. Developers and professional consultants such as architects and engineers must ensure that the appointed contractor constructs the building in accordance with specifications dictated by their respective fields. In particular, professional consultants are more knowledgeable about construction quality than the developers because they determine the construction specifications.

Furthermore, all houses built by a single contractor must be professionally inspected because onsite construction workers have various levels of skill and experience. Therefore, the construction quality of each unit is likely to differ even if the units are in the same phase of project development.

To make sure the high quality of workmanship, the process show in Figure 3 should be practice. Based on Figure 3, periodic inspection should be able to improve workmanship quality by following three key words such as "Who", "How" and "When".

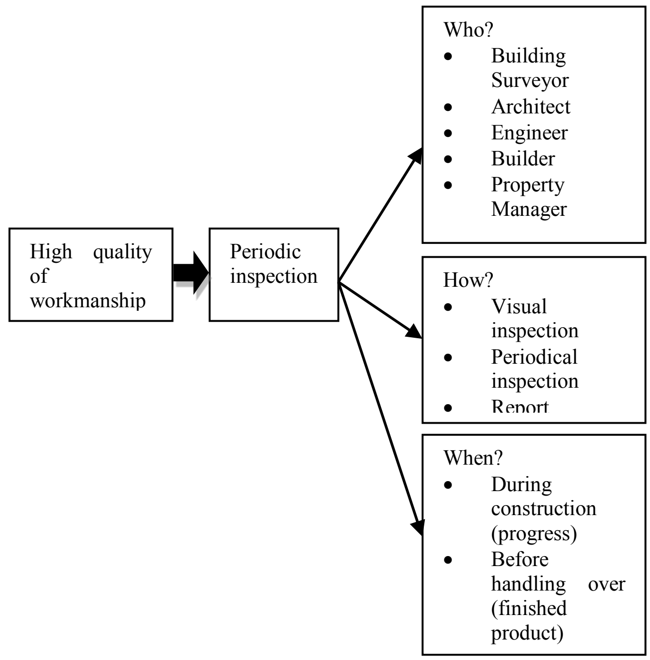


Figure 3 Process flow of inspection to ensure high workmanship quality.

According to "Who" in Figure 3, the following individuals are qualified building inspectors: building surveyors, architects, engineers, builders, and property managers.[18] However, building surveyors are the ideal inspectors because they specialize in the diagnosis of building defects. There are numerous cases in which architects issue the Certificate of Completion and Compliance, or Certificate of Fitness, and yet the building found to be defective.[29] As a result, the buyer receives a defective product. Therefore, building inspectors must be knowledgeable and skilled with respect to the evaluation and reporting of building condition. Even so the certificate has been issued, there must be some form of "check and balance" as to protect the buyer interest from getting defective product, in this case is performing building inspection.

"How" to inspect? Inspections ensure high workmanship quality; thus, an inspector should consider safety, functionality, and aesthetics.[30] Visual inspection is the method that should be used at the first stage of inspection to detect any defect. Then, periodic inspection can clarify building condition during and after construction[31] and detect building defects early. This advanced detection prevents defects from intensifying or occurring in the first place.[32] Most importantly, latent defects are minimized. After inspection, inspectors must generate a report on building condition in case of disputes.

"When" to inspect? To control the workmanship quality of a contractor, building inspection must begin in the construction phase because potential hidden defects are impossible to trace once the building is completed. Some defects also surface before building completion.[33] After completion, the building should then be inspected again before it is turned over to a home buyer to ensure that the buyer receives a house of acceptable quality that is worth its price.

The inspection must be done periodically to prevent any defect. Building defects has major implications and have a chain effect. Firstly, building defect may cause uncomfortable living environment. Then, the minor defect will spread to become major defect and cause other new defect. This may increase the maintenance cost. Major defect also can cause structural failure that trigger building disaster. Finally, it will reduce property value of the houses. These implications indicate that building defect have significant adverse effects on environmental, social and economical aspects.

■5.0 CONCLUSION

The rapid development in housing construction meets the basic human need for shelter. However, widespread defects in provided housing are a public concern. Therefore, the quality of provided housing must be evaluated. As per this research, the quality of provided housing is significantly below standard. Most of the defects are related to architecture at 86.21%. In this field, the floor and the wall are the most defective, accounting for 63.69% of the defects. In terms of defect groups, most defects are linked to the groups of finishing, alignment and evenness, and joint and gap. These types of defects have been asserted by Wai-Kiong and Sui-Pheng (2005) that it is strongly associated with poor workmanship quality.[34] Therefore, workmanship quality should be enhanced to reduce building defects and improve the quality of provided housing.

Workmanship must be emphasized by the relevant parties to improve construction quality. Developers and consultants must monitor the work performed by the contractor to prevent the generation of low quality buildings. Contractors must hire construction workers who are skilled and responsible. Qualified parties must also monitor works consistently on site. Building inspection should be a priority for every housing development, and it should be conducted by qualified person. Periodical visual inspection and report should be done during and after construction before the houses was turned over to the buyers.

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