Journal of Engineering and Applied Sciences 9 (4): 85-91, 2014
ISSN: 1816-949X


# Housing Defect Assessment: Verification of Condition Survey Protocol Matrix via Multiple Logistic Regression

[1]A.H. Samah, [1]K.A. Kosman, [1]A.I. Che-Ani, [2]N.M. Tawil and [1]M.Z. Abd-Razak
[1]Department of Architecture, Faculty of Engineering and Built Environment,
Universiti Kebangsaan Malaysia, Bangi, Selangor,
[2]Faculty of Architecture and Built Environment,
Twintech International University College of Technology, Kaula Lumpur, Malaysia

**Abstract:** The condition of 72 newly completed 2-story terraced houses was evaluated. This study aims to verify the result of Condition Survey Protocol (CSP) 1 matrix analysis and to identify critical defects of the houses based on building components by using multiple logistic regression. The findings showed that the most defective components require, further construction and maintenance. Data were collected by using a building condition survey (visual inspection). The inspection form and reporting procedure were completed based on the format of CSP1 matrix. Statistical package for social sciences was used for the analysis. The CSP1 matrix analysis found 2,119 defects in the houses. The cumulative score was 27,644 and the overall rating was 13.05 which indicate low construction quality and failure of the newly completed terraced houses to pass an acceptable standard for new houses. Results of the multiple logistic regression analysis verified the validity of the CSP1 matrix. Components and sub-components of the houses with the highest number of critical defects were also identified. This study highlighted the defects of the newly constructed houses, as determined in the survey. The findings could assist developers and contractors in improving their construction quality performance.

**Key words:** Terraced houses, building defects, building condition survey, visual inspection, building rating

## INTRODUCTION

A house is one of the basic needs of an individual. Housing demand increases almost every year which causes property values to rise. People dream of owning a house because a house is where they can raise a family. However owning a house is a challenge, particularly for low-income citizens because of increasing housing prices. Ensuring good quality housing is important to give people good value for their money.

Malaysia is continuously working to improve the standard of living of its citizens. Housing development projects, buildings and infrastructure are undergoing the same improvement process. In any country, housing development is crucial to meet the basic needs of people. Unfortunately, based on the current scenario of the Malaysian housing industry, new houses with multiple defects are common in the country. However, this situation does not mean that newly built houses should always be defect free. Manufacturing theory holds that a defective product will appear despite good quality control.

An acceptable construction product is the standard of quality for new housing construction. The standard requires the research of the developer to be acceptable and for construction quality to be improved continuously. Hence, this research is conducted to assess the quality of a newly constructed house and determine whether or not it meets housing quality standards.

**Literature review:** The construction industry is important to the growth of a nations economy because it drives economic development through its multiplier effects on other industries, including manufacturing, finance and education (Hussein *et al*., 2009). The construction industry, also improves the quality of Malaysians lives in terms of various aspects of physical development. International conventions have declared housing a basic human right. Therefore, housing quality is important because it is associated with the quality of life of residents (Yahaya, 1998). Good housing quality indicates that a basic human right is provided. Yahaya (1998) concluded that housing quality could be assessed objectively and subjectively by considering the condition of the house when it was first occupied.

Building inspectors can collect objective data on the status of a building by using a construction standard and

**Corresponding Author:** A.H. Samah, Department of Architecture, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

then reporting the data to the property manager (Straub, 2009). Quality indicators of the condition of the building are based on models developed to measure the performance and quality of the building. Previous research indicated that the Building Environmental Performance Analysis System (BEPAS) is related to the quality indicator. BEPAS was developed based on the life cycle assessment framework for the first building in China (Zhang *et al*., 2004).

Many previous studies investigated defects during post-construction of a building, including its operation and maintenance. However, few studies focused on building defects during the design and construction phases (Josephson and Hammarlund, 1999). The current study focuses on newly completed construction projects and supports the ideas of Josephson and Hammarlund (1999). Such focus was given because building defects at the operational/maintenance phase are influenced by defects that occur in the construction process (Josephson and Hammarlund, 1999).

Tam *et al*. (2000) reviewed the effectiveness of the Performance Assessment Scoring System (PASS) which is implemented to assess the ability of Hong Kong contractors to manage a project according to established standards. The PASS is considered an effective evaluation and incentive system to encourage continuous quality improvement. However, an analysis of PASS scores showed that construction quality did not improve. Therefore, Tam *et al*. (2000) recommended several steps to achieve continuous quality improvement in public housing construction.

Assessing the condition of houses is very important to meet the needs of buyers. According to Crosby (1979), housing quality should meet requirements. Juran (1989) suggested that a quality management system is successful if it averts failures. Quality is defined in the MS ISO 8402-1986 as the properties and characteristics of a product or service that can meet the expressed or implied needs of people. According to Kazaz and Birgonul (2005), homeowners renovate their house because they are dissatisfied with its quality and the services provided in their housing units. This finding supports the statement that quality is related to the needs and wants of the customer.

Evaluating housing condition is also important to ensure the health and safety of occupants. Structural failure may result in loss of life and property damage. Reese (2004), concluded that maintenance significantly influences building safety and the health of the residents. Therefore, assessing housing conditions is essential to obtain information for effective maintenance research. Moreover, housing construction quality is reflective of the skill and reputation of the developer.

Building defects result from the non-fulfillment of intended usage requirements (Josephson and Hammarlund, 1999). Ali described 6 common building defects, namely, crack, moisture, peeling, painting defect, rust and rot. Mokhtar, classified 14 general types of building defects, including leak, bend, rust, rot, moisture, sedimentation and crack. Mokhtar, also stated that some defects occur because of design errors, construction errors and building misuse.

Ramly (2004) analyzed factors of concrete defects in Malaysia and identified 7 types of defects, namely; crack, failed jointing, leaking, corrosion of steel reinforcement, sedimentation, honeycombing and disintegration of concrete that generally occur in concrete structures. Ramly (2004) determined the following 5 main factors of concrete structure defects: Design error, building material, geotechnique, construction errors and unpredicted errors. Ali and Wen (2011) stated that poor worksmanship of contractors is the main factor that contributes to poor construction quality. Such poor worksmanship is caused by insufficient research experience and incompetent work performance. Ahmed *et al*. (2013) identified poor construction quality, as a factor in generating or producing defects.

This literature review suggests that a building condition survey, particularly in newly completed construction products should be conducted to monitor construction defects. A condition survey is part of a professional quality management approach. Professional involvement in quality management improves construction quality (Mills *et al*., 2009). A professional approach supports continuous quality improvement by enabling developers to identify and prioritize the most defective components. This idea coincides with the conclusion of Kian (2001) who stated that authorities should study common defects and work with the construction team to reduce building defects.

## MATERIALS AND METHODS

This study evaluates 72 newly completed terraced houses. The building condition survey is conducted by using protocol 1 (visual inspection) techniques. The research sample is a group of terraced houses located in the housing area of Bangi, Selangor. Table 1 shows the housing projects completed in the research area.

Table 1 illustrates 8 phases of the housing project in the research area. The 6th phase is selected for this research because its completion time is appropriate for the research period. All 72 houses are developed under one development scheme by the same developer and contractor. These houses are assigned codes from R1-72

Table 1: Construction date of housing project phases within the research area

| Project phases | No. of sold units | No. of units | Starting date (construction) | Due date (construction) | Extension of Time (EOT) | Turnkey date (buyers) |
|---|---|---|---|---|---|---|
| 1 | 90 | 90 | 06/11/07 | 05/02/07 | 14/09/09 | 07/10/09 |
| 2 | 60 | 60 | 05/05/08 | 04/08/09 | 25/02/10 | 27/03/10 |
| 3 | 32 | 32 | 05/05/08 | 04/08/09 | 11/12/09 | 08/05/10 |
| 4 | 28 | 28 | 04/02/09 | 04/02/10 | 11/12/09 | 29/04/10 |
| 5 | 79 | 79 | 16/10/08 | 15/01/10 | 30/07/10 | 17/10/10 |
| 6 | 72 | 72 | 12/08/09 | 11/11/10 | 14/03/11 | 29/07/11 |
| 7 | 18 | 18 | 20/11/09 | 19/11/10 | 11/04/11 | 30/12/11 |
| 8 | 37 | 37 | 02/04/10 | 01/07/11 | 03/11/11 | 27/03/12 |

Table 2: Condition assessment protocol 1 (Che-Ani *et al*., 2011)

| Condition | Scale value | Description (value) |
|---|---|---|
| 1 | Good | Minor servicing |
| 2 | Fair | Minor repair |
| 3 | Poor | Major repair/replacement |
| 4 | Very poor | Malfunction |
| 5 | Dilapidated | Damage/missing to replace |

for the analysis. Theoretically, the data can be considered consistent because the product (house) belongs to the same construction project.

The selected project is the construction of 2-story terraced houses. The average floor area of a house is 22×75 square feet. This housing project is designed with a frame structure and a pitch roof that is appropriate for the local climate. Sand brick is the main material for the walls. Most of the houses are finished with tile. This design is typical of terraced houses that are built in Malaysia now-a-days. This study performed CSP1 matrix and multiple regression logistic analyses.

**CSP1 matrix analysis:** The condition of the building component is evaluated by using CSP1 matrix. This code and protocol is one of the guidelines used by the building surveyor to assess any defect based on the condition and priority of every building defect. The CSP1 matrix has its own scoring system (Che-Ani *et al*., 2011) to allow the examiner to carefully and completely assess building conditions. All identified defects are assessed and recorded on-site with the evidence (photos and plan tag). The score obtained from the scoring system determines the level of defects/component by using scale values of good, fair and dilapidated. The possible causes of the defects are also identified. The findings are recorded in the defect sheet and are compiled in the schedule of building condition. Table 2-6 show the scale values acquired from the CSP1 matrix analysis.

Assessment of the condition and priority of a component is fundamental to the CSP1 matrix, as shown in Table 2 and 3. The 5 numerical scores (1-5) are used for assessing the condition and 4 scores (1-4) are employed for evaluating the priorities determined by the scale and description which assist the surveyor in assessing defects.

Table 3: Priority assessments (Che-Ani *et al*., 2011)

| Priority | Scale value | Description (value) |
|---|---|---|
| Normal | 1 | Functional, only cosmetic defect |
| Routine | 2 | Minor defect but can lead to serious defect if left unattended |
| Urgent | 3 | Serious defect cannot function to an acceptable standard |
| Emergency | 4 | Element/structure cannot function at all or risk that can lead to fatality and/or injury |

Table 4: CSP1 Matrix scoring system (Che-Ani *et al*., 2011)

| | Priority assessment | | | |
|---|---|---|---|---|
| Scale | E4 | U3 | R2 | N1 |
| **Condition assessment** | | | | |
| 5 | 20 | 15 | 10 | 5 |
| 4 | 16 | 12 | 8 | 4 |
| 3 | 12 | 9 | 6 | 3 |
| 2 | 8 | 6 | 4 | 2 |
| 1 | 4 | 3 | 2 | 1 |

Table 5: Level of maintenance/services (Che-Ani *et al*., 2011)

| No. | Matrix | Score |
|---|---|---|
| 1 | Simple maintenance | 1-4 |
| 2 | Condition monitoring | 5-12 |
| 3 | Serious attention | 13-20 |

Table 6: Overall building rating (Che-Ani *et al*., 2011)

| No. | Building rating | Score |
|---|---|---|
| 1 | Good | 1-4 |
| 2 | Fair | 5-12 |
| 3 | Dilapidated | 13-20 |

Each defect is recorded based on the condition and priority scales. The values of the scales are multiplied to obtain the rating for a defect. The product of these 2 values provides a value scale of 1-20 that represents the colors green (good), yellow (medium) and red (poor). The scoring system is shown in Table 4.

Table 5 shows the maintenance level to be performed based on the obtained ratings. Table 5 also illustrates that a defect coded in red (score from 13-20) must be given serious attention because it can endanger the tenants of the building. Yellow-coded (score from 5-12) defects require periodic condition monitoring and green-coded (score from 1-4) defects require simple maintenance.

Each building is given a rating that determines its overall condition based on the overall score (Table 6). Scores from 1-4 indicate a good building condition whereas scores from 5-12 indicate a fair building condition. A building is considered dilapidated when it is given a rating from 13-20.

The findings from the condition survey are analyzed by using the CSP1 matrix reporting system. The number of defects, building defects score and building rating are determined by using this method. A photograph box, defects plan tag and executive summary are included for reporting purposes. The research results are simplified in table form.

**Multiple logistic regression analysis:** Multiple logistic regression analysis is conducted to verify the findings of the CSP1 Matrix analysis. The approach is also used to describe the relationship between a dependent variable and several independent variables. Independent variables are often called covariate (Hosmer and Lemeshow, 2000). Multiple logistic regression analysis is a mathematical modeling approach that can be used to describe the relationship of several independent variables with dichotomous dependent variables. Logistic models describe the probability of the dependent variable Y, coded as 0 or 1. This model can be written as follows:

$$\Pr(Y=1)=\frac{1}{1+\exp\left[-\left(\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_kX_k\right)\right]}$$

The formula called logistic function can be expressed as follows:

$$f(z)=\frac{1}{1+e^{-z}}$$

Where:

$$z=\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_kX_k$$

$\beta_k$ coefficients in the logistic model reflect the relationship of the independent variable with the dependent variable. This relationship involves the so-called odds ratio parameters which refer to the ratio of the probability that an event that occurs (e.g., success) divided by the probability that similar events do not occur (e.g., failure). The possibility for a number of events S (e.g., success) is expressed as follows:

$$\text{odds}(S)=\frac{\Pr(S)}{1-\Pr(S)}$$

As an example, if Pr (S) = 0.40 then:

$$\text{odds}(S)=\frac{0.40}{1-0.40}=\frac{2}{3}$$

The result indicates that the probability for the successful event to occur has a 2/3 probability of failure. In other words, the odds of failure events occurring are 3 against 2. The model is generally estimated as follows:

$$Pi=E(Y=1/X)=1/\left(1+e^{-z}\right)$$

Where:

$P_i$ = The probability of the status of house defects
Y = 1 (defective)
Y = 0 (not defective)

This research used a model by Ahmad and Wahid which is estimated based on the equation. The dependent variable value is 1 if the house is defective whereas the value is 0 if the house is not defective. All equation variables are tested to determine which variables significantly affect the house condition.

$$L=\ln\left(P_i/(1-P_i)\right)=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+...+\beta_{40}X_{40}$$

Where:

L = The log of the odds ratio of the status of house defects
$X_{1\text{-}40}$ = House components

## RESULTS AND DISCUSSION

A building condition survey is conducted on the 72 terraced houses. This study discusses the findings of the completed CSP1 matrix and multiple logistic regression analyses.

**CSP1 matrix analysis:** Table 7 shows the result of the CSP1 matrix analysis for all houses. The analysis identified 2,119 defects of which 359 are minor, 234 are fair and 1,526 are major. The cumulative score for the overall defect is 27,644 and the overall rating is 13.05 which indicates poor condition that requires serious attention.

**Number of defects:** The 6 ranges of the number of defects are determined based on Table 8 to simplify the data for all 72 houses. Table 8 shows that the highest number of defects is between 1 and 2. The majority of the 44 houses have defects within the mentioned range. The 15 houses have defects between 26 and 50 and 9 houses have defects that range from 51-75. The 2 houses have defects between the ranges of 76 and 100 and 126 and 150. No house has defects that range between 121 and 125. The lowest number of defects is recorded in R03 with 3 defects whereas the highest number of defects is recorded in R32 with 133 defects. Figure 1 and 2 show a difference

Table 7: Overall CSP1 matrix results

| No. of defects | | | | | |
|---|---|---|---|---|---|
| Minor 1-4 | Fair 5-12 | Dilapidated 13-20 | Total | Overall score/mark | Overall rating |
| 359 | 234 | 1526 | 2119 | 27644 | 13.05 |

Table 8: Number of houses based on the number of defects

| | Number of defects | | | | | |
|---|---|---|---|---|---|---|
| Data | 1-25 | 26-0 | 51-5 | 76-00 | 121-25 | 126-50 |
| No. of houses | 44.00 | 15.00 | 9.0 | 2.00 | 0 | 2.00 |
| Percentage | 61.11 | 20.83 | 12.5 | 2.78 | 0 | 2.78 |

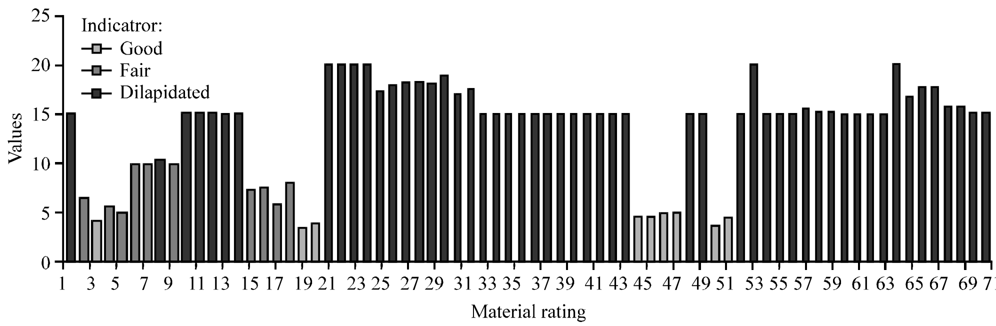


Fig. 1: CSP1 matrix rating for every house

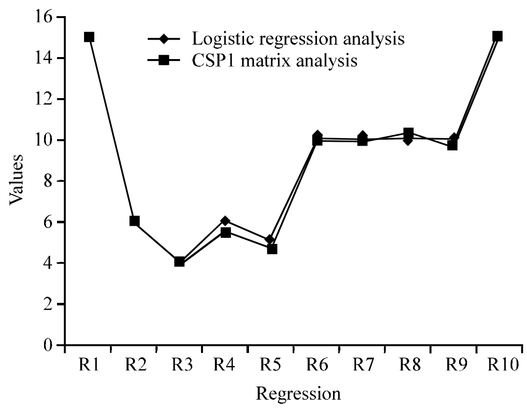


Fig. 2: Line graph shows a comparison of results between CSPI matrix analysia and the logistic regression approach

between the highest and the lowest number of defects. The results also show that the majority (61.11%) of the houses have fewer than 25 defects. However, this percentage does not mean that the houses are in good condition. Housing quality depends on the level of the defects which is discussed in the subsequent section.

**CSP1 matrix rating:** Table 9 shows the number of houses based on the CSP1 matrix rating. The majority of the 52 houses obtained a rating between 13 and 20 and 10 houses acquired a rating between 1 and 4 and 5 and 12 (Table 10). The lowest CSP1 matrix rating denotes that the best rating (3.38) is recorded in house R19. The 5 houses received the lowest rating or highest rating percentage of 20.00 (Fig. 1). Table 9 illustrates that 72.22% of the houses are dilapidated.

Figure 1 shows the CSP1 matrix rating for all houses. The majority of the houses are dilapidated when their rating is >12 (red). This finding shows that the housing quality provided by the developer is poor. Logistic regression analysis is conducted to verify the result and evaluate the condition of the houses.

Table 9: CSP1 matrix rating for the houses

| | CSP1 matrix rating | | |
|---|---|---|---|
| Data | Good (1-4) | Fair (5-2) | Dilapidated (13-0) |
| No. of houses | 10.00 | 10.00 | 52.00 |
| Percentage | 13.89 | 13.89 | 72.22 |

Table 10: Number of defects on selected components and sub-components

| Components | No. of defects | Sub-components | No. of defects |
|---|---|---|---|
| Walls | 891 | Plasters | 631 |
| Door | 389 | Tiles | 539 |
| Floors | 358 | Door leafs | 276 |
| Windows | 135 | Frames | 101 |
| Ceilings | 106 | Side finishing | 81 |

**Number of defects based on building components and sub-components:** This research also studied the building components, apart from the number of building defects, score and rating to discover the potential defective components. The survey result shows that 22 building components have defects. The 5 of these components, namely, walls, doors, floors, windows and ceilings are the most defective ones. The component with the highest number of defects (891) is the wall, followed by doors (389), floors (358), windows (135) and ceilings (106).

The findings also show that the most defective sub-components are closely related to the 5 components. The 40 sub-components are identified in the study, although only 5 sub-components with the highest number of defects are reported. Plasters had the highest number of defects (631), followed by tiles (539), door leafs (276), frames (101) and side finishing (81) (Table 10).

**Verifying CSP1 matrix with logistic regression analysis:** This research aimed to verify the validity of the CSP1 matrix analysis apart from identifying the status of housing defects. The results of the CSP1 matrix analysis are compared with those of logistic regression analysis to verify the validity of the matrix. The 10 houses (R1 until R10) are selected for the comparison. Table 11 shows the

Table 11: Logistic analysis calculation of the sample

| | Samples/house units | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Components | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 |
| Staircase | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 0 | 0 |
| Apron | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Manhole cover | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Frame | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Wooden roof | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Glass | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Door leaf | 3 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 3 |
| Window leaf | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 |
| Hinge | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Valve | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grille | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tile | 7 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 3 | 3 |
| Finishes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Skirting | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 1 | 1 | 0 |
| Concrete | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Reinforce concrete | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Power box | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lamp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Step | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pipe | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Power plug | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Ceiling board | 0 | 2 | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 0 |
| Stair railing | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| Iron cover | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Floor lid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Drain lid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ceiling cover | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Floor trap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Roof surface | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mailbox | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tap | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Plaster | 11 | 4 | 3 | 5 | 8 | 7 | 10 | 7 | 2 | 14 |
| Ceiling frame | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water tract | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Connection | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bolt | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Key set | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| Sink | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Switch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stanchion | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wire | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Average score | 15 | 6 | 4 | 6 | 5 | 10 | 10 | 10 | 10 | 15 |
| Matrix | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Possibility | 0.97348 | 0.783817 | 0.783817 | 0.783817 | 0.597771 | 0.199799 | 0.290835 | 0.17469 | 0.800321 | 0.907221 |
| Defect status | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |

logistic analysis calculation sample for the 10 houses. The average score from Table 11 is mapped toward the CSP1 matrix score for the respective houses (R1 until R10). The findings of the comparison illustrate that the analyses obtained similar results in terms of house condition rating. Figure 2 shows a line graph of the results acquired by the two analyses methods. Figure 2 shows that the results of CSP1 matrix analysis are parallel to those of logistic regression analysis which means that CSP1 matrix analysis is a valid method of identifying the status of building defects. This finding is depicted by the close line between both analyses for all houses.

**Prediction of house defect status:** The results indicate a high defect status. The 52 defects (72.2%) are observed in the involved components whereas not-defective houses have only 20 defects (27.8%) (Table 12). This analysis is completed to assess factors that contribute to house defect status.

The effectiveness of an estimated model is evaluated based on the classification schedule. This schedule provides an accurate predicted percentage based on the developed model. Table 13 clarifies that the resulting model can predict that exactly 70% (14 out of 20) of the houses are not defective. However, the model can predict exactly 94.2% (49 out of 52) for the defective houses only. The overall accurate prediction percentage is 87.5%. This result shows that the reliability of the CSP1 matrix is verified by logistic regression analysis.

Table 12: Frequency of house defect status

| Status | Frequency | Percentage |
|---|---|---|
| Not defective | 20 | 27.8 |
| Defective | 52 | 72.2 |
| Total | 72 | 100.0 |

Table 13: Classification schedule

| | Prediction status | | |
|---|---|---|---|
| Actual status | Defective | Not defective | Correct percentage |
| Defective | 14 | 6 | 70.0 |
| Not defective | 3 | 49 | 94.2 |
| Overall percentage | | | 87.5 |

## CONCLUSION

Given the rapid development of the construction industry, particularly residential construction, housing construction quality should be assessed to ensure that user requirements are met. Such an assessment can guarantee the health and safety of consumers. Moreover, evaluating housing conditions can allow developers and contractors to maintain their good work performance which enhances their reputation.

The findings reveal weak construction quality. The overall CSP1 matrix rating for the houses is 13.05 which indicates that the houses are dilapidated and require serious attention. Urgent maintenance work must be done to meet user requirements and to upgrade the condition of the property.

The wall and the plaster are the largest component and sub-component, respectively that cause building defects. These component and sub-component are significantly correlated with human factor or workmanship. The result indicates that the quality in this construction project does not meet standards which means that the houses are unsuitable for homebuyers.

Multiple logistic regression analysis verified that the results of the CSP1 matrix are reliable and valid with an 87.5% accuracy level which confirms that CSP1 matrix can depict the status of housing defects.

## REFERENCES


Ahmed, A., M. Alam and A. Husain, 2013. Investigation of structural defects and renovation of a RC residential building. Int. J. Chem. Environ. Biol. Sci., 1: 288-292.

Ali, A.S. and K.H. Wen, 2011. Building defects: Possible solution for poor construction workmanship. J. Build. Performance, 2: 59-69.

Che-Ani, A.I., A.S.M. Tazilan and K.A. Kosman, 2011. The development of a condition survey protocol matrix. Struct. Survey, 29: 35-45.

Crosby, P.B., 1979. Quality is Free: The Art of Making Quality Certain. McGraw Hill, New York, USA., Pages: 270.

Hosmer, D.W. and S. Lemeshow, 2000. Applied Logistic Regression. 2nd Edn., Wiley and Sons, New York.

Hussein, J., Z.A. Hamid and M.K. Ghani, 2009. Sustainable construction within the built environment: Malaysian construction industry initiatives. Proceedings of the 11th International Surveyors Congress Plenary Session III-Paper 11, June 18-19, 2009, Kuala Lumpur.

Josephson, P.E. and Y. Hammarlund, 1999. The causes and costs of defects in construction: A study of seven building projects. Autom. Constr., 8: 681-687.

Juran, J., 1989. Leadership for Quality: An Executive Handbook. Free Press, New York.

Kazaz, A. and M.T. Birgonul, 2005. The evidence of poor quality in high-rise and medium rise housing unit: A case study of mass housing projects in Turkey. Build. Environ., 40: 1548-1556.

Kian, P.S., 2001. A review of factors affecting building. Dimensi Teknik Sipil, 3: 64-68.

Mills, A., P.E.D. Love and P. Williams, 2009. Defect costs in residential construction. J. Constr. Eng. Manage., 135: 12-16.

Ramly, A., 2004. Panduan Kerja-kerja Pemeriksaan Kecacatan Bangunan [Guide Works Building Inspection Defects]. Building and Urban Development Institute, Bangkok.

Reese, C.D., 2004. Office Building Safety and Health. CRC Press, Florida, USA.

Straub, A., 2009. Dutch standard for condition assessment of building. Struct. Survey, 27: 23-35.

Tam, C.M., Z.M. Deng, S.X. Xeng and C.S. Ho, 2000. Performance assessment scoring system of public housing construction for quality improvement in Hong Kong. Int. J. Qual. Reliab. Manage., 17: 467-478.

Yahaya, N., 1998. Kualiti perumahan dan kualiti hidup [Quality of housing and quality of life]. Analysis, 5: 133-149.

Zhang, Z.H., X. Wu, X.M. Hui and Y. Zhi, 2004. BEPAS: A life cycle building environmental performance assessment model. Build. Environ., 41: 669-675.