An Expanding Role of Quantity Surveying Practice in Carbon Efficiency

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Abstract
The Paris Agreement came into force on 4 November 2016. Hong Kong plays an important role to help China fulfilling the obligations under the Paris Agreement. The Hong Kong Special Administrative Region (HKSAR) Government published the Hong Kong's Climate Action Plan 2030+ report and set out the new carbon emissions reduction target for 2030. The local construction industry, as one of the major contributors to carbon emissions, is exploring its way to achieve green construction and decarbonization.

This paper attempts to review the current contribution of QS to decarbonization in Hong Kong as well as considering the expanding role of QS in carbon efficiency in the future. The research methodology employed includes literature review, questionnaire survey and case studies.

The findings show that the current construction industry is still at the initial stage to decarbonization. QS's awareness of its contribution to carbon reduction in the construction industry can be increased. Also, challenges may be encountered during the implementation of the carbon reduction strategy.

This research contributes knowledge on the estimation of carbon emission from QS's perspective and involvement of decarbonization in our general practice. Recommendations are suggested to overcome these challenges.

Keywords
Decarbonization, quantity surveying, construction industry, carbon assessment

1 Introduction

1.1 Background

In the past decade, there is a growing recognition that climate change is having more calamitous impacts on ecosystems and human society than expected. To address the climate concern, the world leaders signed The Paris Agreement which aims to substantially reduce global greenhouse gas emission to limit the global temperature increase in this century to 2 degrees Celsius while pursuing efforts to limit the increase even further to 1.5 degrees.

The construction industry plays a dominant role in alleviating anthropogenic climate change and other environmental impacts as researches show that the construction industry generates 40% of the energy-related global greenhouse gas emissions (Chau et al 2015; Akinyemi et al,

2017, MacNaughton et al 2018). Therefore, different countries begin to evaluate the carbon footprint and investigate carbon efficiency in the construction industry. Numerous case studies have been carried out to evaluate the carbon footprint of building construction and effective measures to achieve carbon reduction (Shao et al 2018; Yang et al 2019; He et al 2022) . As one of the members of the construction industry, the quantity surveyors in various countries attempt to explore the solutions in carbon reduction from quantity surveying perspective (Haron et al 2016; Ohueri et al 2019; Ekundayo et al 2019; Lokupathirage et al 2022).

In Hong Kong, the HKSAR Government promotes sustainable and green construction, which echo the way to carbon reduction. Two reports have been published to set out the new carbon emissions reduction target for 2030 and 2050 respectively. Local statutory bodies, for example, Construction Industry Council and Hong Kong Green Building Council Limited, are exploring ways to achieve green construction and decarbonization.

However, there are only a handful of studies that have considered the contribution of quantity surveyors in carbon efficiency and the local-based carbon assessment tools in Hong Kong. Quantity surveyors, normally being regarded as a professional in construction contract and cost, seem not the first-tier players in decarbonization. Limited opportunities are available for quantity surveyors to explore the decarbonization or to conduct the carbon assessment of the project. In order to enhance carbon efficiency in the future, it is valuable to explore their contribution to decarbonization in Hong Kong and the effectiveness of the local-based carbon assessment tools in monitoring the carbon emission of the construction projects.

1.2 Objectives

The aim of this paper is to investigate the quantity surveyors' awareness of enhancing the carbon efficiency and to explore the role of quantity surveyors in this aspect in the construction industry of Hong Kong in the future.

a) The objectives to realise the above aim are: -To identify the current policies on decarbonization in the construction industry
b) To evaluate the current contribution of quantity surveying on decarbonization in the construction industry
c) To explore the role of quantity surveyors in achieving carbon efficiency in construction and provide suggestions to the construction industry

2 Literature Review

2.1 Embodied Carbon in Construction Industry

RICS (2014) defines embodied carbon as:

Carbon emissions associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products. Embodied carbon can be measured from cradle-to-gate, cradle-to-site, cradle-to-end of construction, cradle-to-grave, or even cradle-to-cradle. The typical embodied carbon datasets are cradle-to-gate. Embodied carbon is usually expressed in kilograms of CO_2 e per kilogram of product or material.

Embodied carbon contributes a significant proportion of carbon emission in the construction industry. Chang et al. (2010) found that the energy use in the construction sector accounted for nearly 50% of China's total energy use in 2007 and that the largest contributors to embodied energy in construction were materials, eating, fuels and electricity supply. Chastes et al. (2017) reviewed 90 case studies and found that embodied carbon accounted for 26–57% and 74–100% of the total life cycle carbon emissions of low-energy and near zero-energy buildings, respectively.

Therefore, ascertaining carbon emission on embodied carbon becomes important to achieve the target in the Paris Agreement. Langston et al. (2018) investigated the embodied carbon for refurbished buildings and new-build projects in Hong Kong. It suggested that embodied carbon for refurbished buildings is 33-39% lower than new-build projects, and the cost for refurbished buildings is 22-50% lower than new-build projects. Embodied carbon ranges from 645-1,059 kgCO2e/m2 for new-building and 294-655 kgCO2e/m2 for refurbished projects in Hong Kong.

2.2 Role of Quantity Surveyors towards Decarbonization in Other Countries

Quantity Surveyors in different countries start to evaluate their role in sustainable construction projects and suggest their way out in the construction industry.

In Malaysia, Haron et al (2016) investigated the challenges of quantity surveying practices in sustainable construction projects. Later, Ohueri et al (2019) proposed the integration of BIM and local sustainability rating tools such as Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) which enables the project team to make sustainable analyses and decisions at the conceptual stage of design.

In the United Kingdom, Ekundayo et al (2019) reviewed the open sources UK tools for embodied carbon counting and suggested that an industry-agreed data structure and common methodology is needed for embodied carbon counting.

In Sri Lanka, Lokupathirage et al (2022) discovered that awareness of quantity surveyors at basic concepts of carbon emission was considerably low and recommended a major revision in the Green Building code, with special reference to the carbon account concept as a fundamental application.

2.3 Decarbonization in Construction Industry in Hong Kong

Refer to the 2021 Global Status Report for Buildings and Construction, the carbon emission from the buildings and construction sector have fallen to 2007 levels in 2020. The current decline is due mostly to the COVID-19 pandemic. Also, since 2015, more countries have adopted policies and codes that may have a future impact on the emissions and energy efficiency of the buildings.

In Hong Kong, the HKSAR Government has been taking action to achieve decarbonization. The Environment Bureau published Hong Kong's Climate Action Plan 2030+ in 2017. In October 2021, the Environment and Ecology Bureau, replacing the Environment Bureau, published Hong Kong's Climate Action Plan 2050. The plan evaluated the previous actions and developed strategies to achieve zero-carbon emissions in the next decade. Thereafter, various departments introduced decarbonization in their projects. The Architectural Services Department devoted efforts towards adopting innovative, sustainable and smart building

designs to drive the efficient utilisation of energy, material and land resources. The Hong Kong Housing Authority has adopted the concept of "Sustainable Community for Green and Healthy Living" in the design and planning stage for new development projects by way of green and low-carbon measures throughout the building development cycle.

Hong Kong Green Building Council (HKGBC) established a Sustainable Development Committee to accelerate the decarbonization of the built environment in Hong Kong. The Construction Industry Council (CIC) has created a Carbon Assessment Tool, which is a common platform to evaluate the carbon performance of buildings and infrastructure in Hong Kong. It also launched the Sustainable Finance Certification Scheme to support green construction from the financial aspect. The CIC and HKGBC also jointly develop the CIC Green Production Certification to assess the sustainable building and construction materials / products and identify the low carbon construction products.

2.4 Role of Quantity Surveyors towards Decarbonization in Hong Kong

Traditionally, the quantity surveyors in Hong Kong are responsible for the cost and contract management for the construction project. According to The Hong Kong Institute of Surveyors (HKIS), the core services of quantity surveying include cost planning, value management, preliminary cost advice, procurement methods, tendering, valuation of construction work, cost control and financial management, etc.. There is no express role of quantity surveyor in decarbonization.

Nevertheless, quantity surveyors in Hong Kong have been actively involved in supporting the green and sustainability building development. HKIS has established a Working Group on Sustainability (merged with the Working Group on Green Building) to promote and to provide continuous input to the construction industry on sustainability construction. Carbon emission is also one of the areas of study by the Working Group.

It is found that there is little local research in exploring carbon emission from the quantity surveying perspective and how the quantity surveyors can be involved in enhancing carbon efficiency. Therefore, it is worth investigating this topic.

3 Methodology

This research is mainly conducted by using questionnaire survey and case study.

3.1 Questionnaire Survey

The purpose of the survey is to review the opinion and cognition of the quantity surveyors and their relevant knowledge to decarbonization in Hong Kong.

To get an overview of the quantity surveyors on decarbonization in Hong Kong, the questionnaires were sent to around eighty (80) individual quantity surveyors who are currently practising in Hong Kong with over five (5) years experience. This ensures the respondents are familiar with the local construction practice. Also, the participants with background from the client, consultant, contractor and others were invited to take part in the survey with an aim to enhance the representation of the survey result. The questionnaire survey was divided into four (4) parts:

Part 1 Background - to identify the experience of respondents in quantity surveying practice, their background in the construction industry and experience in carbon assessment.

Part 2 Understanding on Decarbonization in Hong Kong - to evaluate the respondents' understanding on the policies, strategies and measures adopted in Hong Kong regarding decarbonization.

Part 3 - Role of QS in Enhancing Carbon Efficiency - to examine the role and contribution of quantity surveyors in achieving carbon efficiency, from the design stage up to the construction stage.

Part 4 - Ways to Enhance Carbon Efficiency - to explore the respondent's view on various ways of reducing carbon emission at different stages of development.

For the data collection, processing and analysis, this is an online survey conducted in English with an electronic data collection platform "Google Forms". Responses were collected and the results summary was generated after the closing of the survey. The survey was conducted anonymously. The result will be reviewed and analysed in the next section.

3.2 Case Study

While the survey focuses on the quantity surveyors' view and contribution in the decarbonization in Hong Kong, embodied carbon was a popular area of concern and carbon assessment was carried out from the perspective of quantity surveyors to get a more in-depth study in this regard. Quantity surveyors are familiar with the pricing breakdown of a construction project and involved in the quantities measurement, billing and pricing of materials and works items in their daily practice. It is suggested that the quantity surveyors are one of the appropriate parties to take part in assessing the embodied carbon emission of a construction project.

The case study adopts the CIC Assessment Tool to evaluate the environmental impacts of using low carbon building materials. A private residential building located in Kowloon East of Hong Kong, with a construction floor area (CFA) of around 8000m2 and a construction period of 26 months was selected.

It is understood that increasing the housing supply in both private and public sectors was one of the important government policies and a total housing supply target of 430,000 units was set for the coming 10-year period. Among private real estate development projects, the statistics from the Census and Statistics Department between 2019 to 2021 reveals that there are around 160 - 210 numbers of residential projects during the years, which constitutes around 65% of all the private real estate development. It is expected that residential development is one of the major types of project contributing to the carbon emission and hence a private residential development was selected in this case study.

The assessment covers the major structural elements and materials used in the building foundations, building core structure, and temporary works involved in the construction process. As the development is a typical reinforced concrete building, materials such as concrete, reinforcement bar and formwork are the focus of the study.

There are two design schemes in the case study, namely the Design A and Design B. Design A can be regarded as the base scheme, which is the original design of the project based on the

contract drawings and the specification. Design B was developed based on the base scheme, except with the incorporation of construction materials with high carbon efficiency. In this case study, construction materials listed as the certified products in the CIC Green Product Certification and suppliers under the list were contacted to identify the high carbon efficiency materials used in the study.

By calculating the carbon emission level for Design A and Design B, a comparison of the effect of using high carbon efficiency materials can be distinguished. The study further analyses the carbon reduction efficiency in using the materials, by examining their performance of carbon saving and incurred extra cost.

4 Findings and Discussion

4.1 Findings and Discussion from Questionnaire Survey

When the survey was closed, 72 responses were collected. Respondents were asked for the number of carbon assessments participated in the construction industry. 83% of the respondents had experienced less than 3 nos. of carbon assessment. This suggests that not many quantity surveyors may not have experience in projects with carbon assessment. This may be because carbon assessment in construction is still not a very popular topic and has not been introduced in most of the construction projects.

The second part of the questionnaire survey evaluates the respondents' understanding on decarbonization in Hong Kong. Respondents were asked for the agreement related to decarbonization, local green initiatives / strategies, publication and carbon emission contribution.

89% of respondents noted that the Paris Agreement was signed to limit the increase in global average temperature to well below 2 degrees Celsius. Over 80% of respondents were aware of the BEAM Plus scheme which was commonly adopted in the construction industry. Only 25% of respondents know the latest publication "Hong Kong's Climate Action Plan 2050" regarding zero carbon emission in Hong Kong. This reveals that the respondents are not familiar with the latest policies or strategies imposed by the HKSAR Government for decarbonization.

The third part of the questionnaire survey examines the role of quantity surveyors in enhancing carbon efficiency. Likert scale questions were asked to identify the attitude of the quantity surveyors towards enhancing carbon efficiency.

66.6% of respondents disagree or are undecided on the importance of a quantity surveyor' role in enhancing carbon efficiency. Also, the respondents were asked on quantity surveyors' contribution in enhancing carbon efficiency. Only 25% of respondents consider quantity surveyors can contribute in calculating carbon emission / carbon footprint of the project. There are questions regarding the stage and the way for quantity surveyors to be involved in enhancing carbon efficiency. 83% of the respondents consider that quantity surveyors can be involved in enhancing carbon efficiency in the pre-contract stage (i.e. feasibility study, design / detailed design and tendering).

It reveals that the quantity surveyors are uncertain about their role in enhancing carbon efficiency and the sense of contributing carbon assessment is relatively weak in Hong Kong. The possible reasons are the lack of participation in projects with carbon assessment and their

unfamiliarities with the decarbonization in construction. This also brings out the topic on whether and how the role of quantity surveyors should be expanded to cope with the decarbonization, and more questions were asked in this part.

Although not all the respondents are familiar with the role of quantity surveyors in decarbonization, all the respondents agree that the tender documents should include requirements relating to enhancing carbon efficiency and 61% of respondents agreed that carbon efficiency shall be included as one of the assessment criteria in the tender evaluation.

Respondents are aware that incorporating carbon assessment in the tender document as well as tender evaluation is an effective way in promoting carbon efficiency. In fact, some countries have imposed policies on carbon assessment in the construction development. For example, Policy SI 2 F of the London Plan 2021 requires all planning applications with a Whole Life-Cycle Carbon assessment.

In answering the questions on what kind of information can be included in the tender documents and tender evaluation to enhance the carbon efficiency, 83% of the Respondents agreed to include Carbon Reduction Requirement, and 70% of the Respondents mentioned about the BEAM Plus requirement. Much input and advice may be required from the quantity surveyors on preparing the carbon reduction requirement, especially in striking a balance between the carbon reduction and cost effectiveness.

In view of the fact that quantity surveyors may face difficulties in performing their role in decarbonization, questions were asked to identify the obstacles, additional skills and knowledge for quantity surveyors in enhancing carbon efficiency. The following table shows the potential obstacles faced by the quantity surveyors:

Description	Frequency	Percentage
Lack of knowledge on the carbon emission calculation	11	15%
Lack of database for calculating the value of carbon emission	21	29%
Insufficient time to carry out a carbon emission monitoring	28	39%
Additional cost incurred for monitoring the carbon emission	12	17%

Table 1 - Potential obstacles faced by the questionnaire survey respondents

It seems the respondents are concerned about the time required in monitoring the carbon emission, especially when the carbon reduction becomes part of the tender requirements. Besides, they prefer to have a database to facilitate their valuation of the carbon emission of a project. This is understood as the carbon assessment may be somehow similar to the cost assessment of a project from the mindset of quantity surveyors. While the latter one requires a cost database, the former one will have a carbon level database.

In answering the questions on the additional skills required for a quantity surveyor to expand its role in decarbonization, 54% of the respondents consider the knowledge of measuring carbon emission of a construction project and 17% of the respondents consider the knowledge on sustainable construction materials are important. On the other hand, 15% of the respondents link up the Building Information Model (BIM) with decarbonization, which can be an area to further explore.

The fourth part of the questionnaire survey further explores the ways to enhance carbon efficiency in the construction with the respondents.

In terms of the strategies, 67% of the respondents agree that the government should have a dominant role in enhancing carbon efficiency. This is not surprising as more than 40% of the construction projects in Hong Kong belong to the public sector. Without the support from the HKSAR Government, the stakeholders in the construction industry will have less incentives to enhance carbon efficiency.

In terms of the procurement, around 40% of respondents support the introduction of named suppliers and 40% of respondents suggest the implementation of a supply chain management system to the tender document. Introduction of named suppliers is an effective way in the short term to ensure the low carbon material can be used by the tenderers. In the long term, the implementation of a supply chain management system facilitates the procurement of the low carbon materials.

Attention was also drawn to the influence of transportation to decarbonization. Around 50% of the respondents fail to identify that transportation planning should be included in the carbon estimation during the design stage. In fact, transportation related activities contribute a significant part of carbon emission. In another question on sustainable transportation method, 50% of the respondents are able to choose barge transportation as the lowest carbon emission method. Carbon estimation at various stages can be an area to further explore by the quantity surveyors.

The results of the questionnaire survey identifies the challenges that quantity surveyors may face in implementing carbon reduction strategies. The quantity surveyors may not have a chance to take part in a project involving substantial decarbonization elements can be an obstacle. Despite the continuing effort of the government and the construction industry to promote low carbon construction, the incentive to focus on carbon emission may not be sufficient. For example, the GFA concession for the project offers a strong financial incentive for the developers to join the BEAM Plus assessment. To date, there is no direct carbon emission related incentive introduced by the government.

Nevertheless, the quantity surveyors can be a facilitator in promoting and implementing carbon efficiency requirements and measures to construction, and even take part in setting the carbon reduction requirements and incorporating them as part of the tender requirements. Further, quantity surveyors may, based on their skills and knowledge in quantity and cost of the construction, take part in the carbon estimate and assessment. There are abundant opportunities for the quantity surveyors to explore further.

4.2 Findings and Discussion from Case Study

A case study using the CIC Carbon Assessment Tool on a private residential project was carried out from the perspective of quantity surveyors. The assessment covers the major structural elements of the building, with materials such as concrete, reinforcement bar, formwork, etc. involved.

As explained in the methodology, the study has compared the Design A, which is the base scheme without considering any environment friendly materials, with Design B, which materials with high carbon efficiency for concrete, reinforcement bar and prefabricated reinforcement bar are adopted.

4.2.1 Carbon Emission Performance

The comparison between Design A and Design B is illustrated in Figure 1 and 2 :-

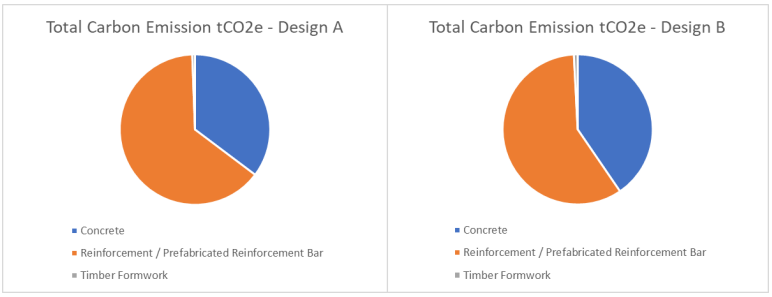

Figure 1 - Comparison between Design A and Design B on total carbon emission (diagram)

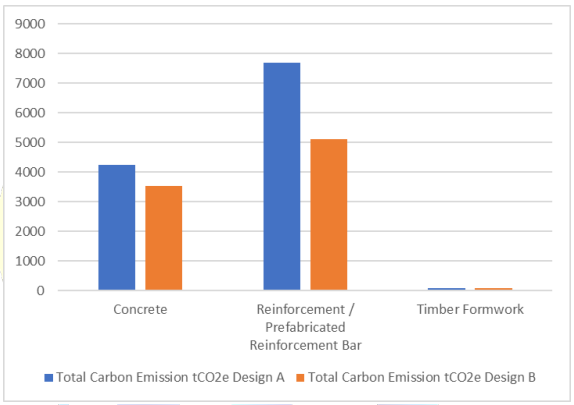

Figure 2 - Comparison between Design A and Design B on total carbon emission (bar chart)

It is not surprising that the total level of carbon emission has been significantly reduced in Design B after incorporating the high carbon efficient materials. A comparison between the adopted material can be summarised as below:

Elements	Design A		Design B		tCO2e Deduction %
	Material	tCO2e [A]	Material	tCO2e [B]	([A]-[B])/[A]
Concrete					
- Grade C35	≤25% PFA mix	1,160	35-55%GGBS mix	674	41.9%
- Grade C45	≤25% PFA mix	1,634	35-55%GGBS mix	1,491	8.8%
- Grade C60	≤25% PFA mix	1,440	35-55%GGBS mix	1,361	5.5%
Reinforcement Bar	General Reinforcement	7,654	High recycled content (≥60%)	5,088	33.5%
Prefabricated Reinforcement Bar	General Reinforcement	48	High recycled content (≥60%)	31	35.4%

Table 2 - Difference analysis between Design A and Design B on carbon emission by major elements

It is observed that for concrete, when choosing 35% - 55% Ground Granulated Blast-furnace Slag (GGBS) as a cement substitute instead of Pulverised Fuel Ash (PFA), the carbon emission of concrete with grade C35 will be deducted for almost 42%.

PFA is often added to the cement as a substitute with a maximum up to 35% of the cement. As an alternative, GGBS can be used instead of PFA and have a replacement ratio up to 75% of the cement. As the production of cement will generate a lot of carbon dioxide, the use of GGBS in concrete can better help to reduce the carbon emission. On the other hand, the cost of cement mixed with GGBS is nearly the same as that of cement mixed with PFA, with only a difference of HK$20 per meter cube. Therefore, it is a sustainable way to substitute PFA with GGBS.

For reinforcement bar / prefabricated reinforcement bar, when choosing rebar with high recycled content (>=60%) instead of general newly produced reinforcement, the carbon emission will be deducted for around 35%.

Steel is recyclable and can be re-melted to produce new steel of the same quality. The iron atoms are indestructible, and therefore steel can be produced from recycled steel scrap without compromising the quality. However, recycled materials cannot be tested from laboratory reports. Instead, they can be verified through the tracking process of all materials in the product production process. It is necessary to track all materials through the production process to calculate the percentage of recycled content in the final products. As a result, the overall price of rebar with high recycled content will be around 20% - 30% higher than the general newly produced reinforcement.

For the timber formwork, given its reusable and recyclable nature, it generates relatively limited carbon dioxide between the Design A and B. This explains the major difference in carbon performance between the two major groups of materials. The materials used in the temporary works are usually reusable and recyclable and hence their level of carbon emission is lower when compared to those of permanent nature.

4.2.2 Cost / Carbon Reduction Efficiency

A comparison between the overall cost increasing and relevant saving in carbon emission between Design A and Design B is summarised as following:

Elements	Design A		Design B		Cost Increasing %	tCO2e Saving %
	Cost	tCO2e	Cost	tCO2e		
	HKD per CFA	per CFA	HKD per CFA	per CFA		
	[A1]	[B1]	[A2]	[B2]	([A2]-[A1])/[A1]	([B2]-[B1])/[B1]
Concrete	2,287.09	0.53	2,316.29	0.44	1.3%	-17.0%
Reinforcement Bar / Prefabricated Reinforcement Bar	4,124.13	0.96	5,155.16	0.64	25.0%	-33.3%
Overall	6,411.22	1.49	7,471.45	1.08	16.5%	-27.5%

Table 3 - Relationship between cost and carbon emission under Design A and Design B

The efficiency of a low carbon material takes into account two major aspects: its carbon emission performance and its associated cost. It is found that the carbon saving achieved in reinforcement bar or prefabricated reinforcement bar is relatively higher than the one in concrete in a project. This is not only because of the carbon emission performance of the materials, but also due to the quantities involved in the project. Generally speaking, the quantity reinforcement bar (in kilogram) involved must be higher than the volume of concrete (in meter cube) needed in a project. Therefore, the volume or quantity of the materials involved is also an important factor when assessing the carbon emission performance.

Nevertheless, if we consider the carbon emission performance together with the extra cost involved, it is not difficult to find that concrete can achieve a relatively high carbon reduction by only an increment of 1.3% of the relevant cost. Therefore, it is useful to focus on the cost instead of only the carbon reduction level when we are considering the implementation of any carbon reduction measures.

As such, a cost/carbon reduction efficiency ratio can be developed to identify the optimum use of carbon efficient materials.

$$Cost/Carbon\ Reduction\ Efficiency\ Ratio\ =\ Cost\ Change\ (\%)\ \div tCO2e\ Saving\ (\%)$$

If the ratio is negative, it means an increasing cost in the project as a result of the carbon reduction. If the result is positive, it means there is a saving in cost and a reduction in the carbon emission. The closer the ratio to zero, the more efficient the carbon reduction measures. This ratio is operative on the condition that a certain level of carbon reduction must be achieved.

In this case study, the Cost/Carbon Reduction Efficiency Ratio is calculated as -0.08 for concrete and -0.6 for reinforcement / prefabricated reinforcement bar, which demonstrated that concrete can achieve a relatively carbon reduction efficiency without much cost implication.

4.2.3 Discussion

The study shows that the use of high carbon efficiency materials can effectively reduce the carbon emission level of a project. The level of reduction is largely subject to the extent of relevant materials used. To begin, it may be effective to focus on some major elements with significant quantities, such as the concrete and reinforcement bar. Quantity surveyors are sensitive to the quantities of construction materials in a project and are capable of identifying those potential materials for further study.

In searching for the high carbon efficiency materials, it is found that the reasons for higher cost for this kind of materials may not only be limited to the source of raw materials or the production methods. This is the case for reinforcement bars as the use of re-melt and re-produced reinforcement bars cannot be examined in a laboratory condition and a third-party verification is required during the production. Whether the extra cost of hiring a third-party verification can be reduced could be a subject to be explored by the quantity surveyors.

The carbon assessment is merely a calculation process, however, the subsequent analysis is essential in order to achieve a cost effective carbon reduction for a project. Based on the studies, we need to take into account (i) the quantities and proportion of the materials in a project, (ii) the level of carbon reduction the materials can be achieved, (iii) the associating additional cost to be incurred and the (iv) cost/carbon reduction efficiency ratio representing the efficiency in using the carbon efficient materials.

It is understood that this study has not considered some other technical factors when using high carbon efficient materials. These technical factors include the availability of the supply, lead time for the materials production and transportation, whether unique work sequences or fixing methods are needed, special care during the maintenance etc.

As a matter of fact, one of the suppliers listed in the CIC Green Product Certification expressed that due to the low demand and limitation in the logistics, it is uneasy to place the order of the certified products on the list. Apart from the carbon reduction efficiency, the construction industry will need to overcome the technical considerations and limitations in order to widely promote the use of high carbon efficiency materials in Hong Kong.

5 Recommendation

The questionnaire concludes that the role of quantity surveyors in the aspect of decarbonization is to be further explored and expanded in Hong Kong. Whilst the quantity surveyors have a knowledge on the concept and some policies on decarbonization, the opportunity for them to take part and actually be involved in decarbonization is limited. The quantity surveyors may also need to equip themselves so that they are really to take up the new role regarding decarbonization.

At the government level, it is recommended that more incentives should be introduced to encourage the implementation of decarbonization in construction. These incentives will help to overcome the financial need for project development, so that more projects will address the concern of carbon emission in a practical way. It is also suggested that the government takes the carbon efficiency requirement as part of the building approval procedures. For instance, a building development project should conduct a carbon estimate as part of the submission to the Building Authority for approval. This allows the stakeholders to consider carbon emission without any exercise.

At the industry level, it is recommended that more guidelines or information be made available regarding the implementation details of decarbonization measures. At this moment, there is no definition of what is meant by a successful carbon reduction project. How can the carbon performance of a project be assessed? Who is the one who administers the carbon assessment or what kind of standard is to be achieved? A local-based carbon emission standard for the construction industry is recommended to be published to allow the stakeholders, including the quantity surveyors, to estimate the carbon emission of material, plant and equipment from design to construction stage.

For the quantity surveying professions, the quantity surveyors should be aware of the importance of decarbonization. They shall appreciate and make use of the existing tools and information available in the construction industry, and explore the way forward to achieve decarbonization from the perspective of quantity surveying. For example, based on the cost estimating technique, quantity surveyors can conduct carbon estimation for projects in the design stage. By building a database of carbon emission, which is similar to a cost data library, carbon estimation can be done in an effective way.

Besides, based on the knowledge in tendering and contract management, it is not difficult for the quantity surveyors to prepare the low carbon requirements in a tendering stage. It is also practical to include carbon efficiency as one of the tender evaluation criteria. Further, with the expertise in quantity and cost of a construction project, the quantity surveyors can make use of

the bills of quantities and transform it into a useful tool for carbon assessment. The quantity surveyors should also be capable of advising clients on the efficiency in using green products, materials, plants and equipment.

To be ready to take part in decarbonization, quantity surveyors are required to equip themselves with knowledge such as carbon emission, carbon assessment and the cost information associated with decarbonization. Quantity surveyors should change their mindset and be aware that decarbonization is in fact closely related to construction cost and contract which the quantity surveyors have a role to play. On the other hand, joint efforts between the practitioners in the construction industry are essential to enhance the implementation of decarbonization measures. Reducing carbon emission is a mission for everyone.

6 Conclusions

The overriding purpose of this paper is to explore and promote the quantity surveyors' contribution on carbon efficiency which facilitates sustainable construction in Hong Kong.

As one of the important players in the construction industry, decarbonization could not be successful without the participation and support from the quantity surveyors. Quantity surveyors possess the necessary knowledge and skills in the construction cost and contract which can facilitate the implementation of any decarbonization measures from the cost and contract management perspective.

To conclude, there is no doubt that more can be done by the quantity surveyors in decarbonization, to make use of their professional knowledge in supporting not only the construction industry, but also protecting the environment. By expanding the role of quantity surveyors in decarbonization, they can facilitate and support the implementation of decarbonization in the construction. Quantity surveyors should be open-minded, be ready to embrace the new changes to the construction industry and ready to take up the role in protecting our living environment.

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