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Integrating clean development mechanism into the development approval process of buildings: a case of urban housing in Uganda

Nathan Kibwami* and Apollo Tutesigensi

Institute for Resilient Infrastructure, School of Civil Engineering, University of Leeds, Leeds, LS2 9JT, UK.

Abstract

Since climate change is no respecter of geographical boundaries, concerted mitigating actions such as clean development mechanism (CDM), are desirable. In CDM, developed countries can earn certified emission reduction credits from emission reduction projects undertaken in developing countries. Recent research suggests that, theoretically, CDM can be extended to the building sector. However, there is limited research on how CDM can be integrated in the development approval process (DAP) of buildings. This paper presents an investigation on how CDM could be integrated into the DAP of buildings in urban Uganda. A method of process modelling was used to describe the existing DAP, and also to design a new DAP. To demonstrate how CDM could be integrated into the new DAP, a typical dwelling unit was used. Two options for the dwelling were considered: a baseline (i.e. constructed using typical materials, plant, and workforce) and alternative (i.e. constructed using provisions to reduce carbon emissions). The difference in emissions in the two options constituted the basis for a CDM. Results suggested that the existing DAP does not consider carbon accounting and thus was not congruent with CDM modalities. A new DAP which is compatible with CDM was proposed. When the CDM concept was integrated into the new DAP, a bottom-up projection regarding construction of 28,000 houses annually within the capital city showed that reductions of over 200 ktCO_2 could be achieved in a period of 10 years. These figures were comparable with prevailing CDM initiatives. The structure of a CDM programme aided by the new DAP was presented and discussed. This study shows that integrating CDM into the DAP of buildings in Uganda is possible if assessment of carbon emissions is incorporated in the existing DAP. The overall findings suggest that CDM could promote market-based mechanisms of enhancing sustainable construction in developing countries.

Keywords: Building projects; carbon emissions; clean development mechanism; planning approval.

*Corresponding author (Tel.: +44 (0)7766 576 749; Fax: +44 (0) 113 343 2265; and Email address: cnnk@leeds.ac.uk

Highlights:

- The study investigates integration of clean development mechanism into the development approval process for buildings in Uganda.
- A new development approval processes which considers assessment of carbon emissions associated with building projects is proposed.
- Within Kampala, the capital city of Uganda, integrating clean development mechanism into the proposed development approval process can lead to emission reduction of over 200 $ktCO_2$ in a period of 10 years.
- It is possible to devise market-based mechanisms of enhancing sustainable construction in the urban sectors of developing countries.

1. Introduction

Reducing greenhouse gas (GHG) emissions requires concerted efforts because climate change is everyone's problem. To this end, the concept of clean development mechanism (CDM) was conceived. CDM provides a global platform for developed and developing countries to offset emissions through emissions trading (Gillenwater & Seres, 2011). The emissions traded arise from emission reduction projects, such as afforestation, that are undertaken in developing countries. The aim of CDM, according to the Kyoto Protocol, is twofold; developed countries are enabled to meet their emission reduction targets whilst facilitating developing countries to achieve sustainable development. In that way, CDM emerges as a 'win-win' strategy for countries in jointly tackling climate change.

Recently, the building sector, which accounts for one-third of the annual global carbon emissions (Roodman & Lenssen, 1995; UNEP, 2009; WBCSD, 2012), has been identified as a potential beneficiary of CDM. In Zhou, Li, and Chiang (2013), CDM was identified as a viable solution to alleviate barriers impeding promotion of energy efficient buildings in China. Mok, Han, and Choi (2014) explored the potential of implementing CDM in the building sector and concluded that there are several emission reduction opportunities fit for CDM, albeit scattered along the lifecycle of building projects. Chen, Jiang, Dong, and Huang (2015) proposed a CDM energy performance based method to reduce transaction costs in implementing CDMs in China's building sector. Lam, Chan, Yu, Cam, and Yu (2015) explored the applicability of CDM in the Hong Kong building sector and identified some barriers and potential solutions. However, besides the paucity of CDMs related to buildings (Cheng, Pouffary, Svenningsen, & Callaway, 2008; Hinostroza et al., 2007; Novikova, Ürge-Vorsatz, & Liang, 2006), there are no studies yet to suggest how CDMs can be integrated in the development approval process of buildings, yet the greatest potential to reduce carbon emissions from a building is in decisions made in the earliest stages of its life cycle (BRE and Cyril Sweett, 2005; Goggins, Keane, & Kelly, 2010; Jowitt, Moir, Grenfell, & Johnson, 2012). This paper therefore investigates how the CDM can be integrated into the development approval process of buildings, with a focus on urban housing in Uganda.

2. Background

This section provides a brief background on the CDM concept and why this concept should be considered in addressing housing shortage in urban areas of Uganda.

2.1. The CDM concept

The CDM concept was established under the Kyoto Protocol (Article 12), an international treaty to reduce GHG emissions. Developed countries that are signatory to this protocol (i.e. Annex 1 countries) committed to reduce their GHG emissions. In the first commitment period (2008 to 2012), the countries committed to reducing their emissions by 5% of 1990 levels. The second commitment (2013 to 2020) stipulated reduction of emissions by 18% below those of 1990 (UNFCCC, 2013a). To provide flexible market-based mechanisms of meeting emissions reduction commitments, the CDM concept was introduced (Kyoto Protocol, Article 12). In CDM initiatives, the Annex 1 countries can purchase certified emissions reduction (CER) credits, each equivalent to one tonne of emissions avoided. The purchased CER credits can then be used to offset emission reduction targets. However, the CER credits must have been generated from emission reduction activities (e.g. planting of trees, renewable energy projects, energy efficiency measures etc.) undertaken in the participating developing countries (i.e. non-annex 1 countries) (Kyoto Protocol, Paragraph 3a). While the CDM has not been without its challenges and controversies (Gillenwater & Seres, 2011; Hinostroza et al., 2007; Winkelman & Moore, 2011), it has arguably remained the best available global concerted effort of tackling climate change by establishing a market for GHG emission reductions.

2.2. Need for CDM in urban housing

It is estimated that 40% of the population in Africa lives in urban areas but this figure is envisaged to rise over 50% by 2050 (United Nations, 2015). With such rapid urbanisation, a persistent rise in the demand for housing in urban sub-Saharan Africa is expected. In Uganda, addressing housing shortage in the capital city alone requires constructing over 28,000 houses annually for at least 10 years (UN-HABITAT, 2010, p.37). However, addressing this housing deficit has not been without unintended consequences. Construction activities in Uganda negatively affect the environment, especially due to unsustainable processes of material production (Muhwezi, Kiberu, Kyakula, & Batambuze, 2012). The technologies used in energy production are highly inefficient, and associated with high levels of pollution (Okello, Pindozzi, Faugno, & Boccia, 2013). The predominant method of constructing urban houses using burnt bricks and cement mortar (UBOS, 2010) is highly associated with carbon emissions since cement and bricks are both energy and carbon intensive materials (Hammond & Jones, 2008; Monahan & Powell, 2011). A recent study (Hashemi, Cruickshank, & Cheshmehzangi, 2015) found that the average energy consumed in small-scale brick manufacturing in Uganda is 5.7 times higher than that in developed countries. In order to pursue a low carbon path to development, in which case implies shrinking the housing deficit in urban Uganda sustainably, consideration of CDM is desirable.

It is against this background that the authors sought to contribute towards the understanding and possible realisation of sustainable urban housing development in Uganda, by proposing the integration of CDM in the development approval process. The proposal culminated from pursuit of three objectives:

1) to describe the existing development approval process (DAP), hereinafter referred to as the as-is DAP,
2) to propose a new development approval process, hereinafter referred to as the to-be DAP, and
3) to demonstrate how CDM can be integrated into the to-be DAP.

The following section identifies the methods used to achieve each of the objectives.

3. Methodology

It was necessary to understand the existing practices before any proposals for improvement could be made. To achieve this, the as-is DAP of buildings was described using the method of process modelling. Process modelling, which is used for descriptive purposes, is often motivated by the need to improve a prevailing process (Aguilar-Savén, 2004; Chinosi & Trombetta, 2012; Fernández et al., 2010) hence it was an appropriate method to adopt. The method of process modelling involved three stages: process discovery, process mapping, and empirical verification (Debevoise & Geneva, 2011; Verner, 2004). In the first stage, relevant subprocess of the as-is DAP were identified. In the second stage, the identified subprocesses were transformed into a process model representing the as-is DAP. In the third stage, the process model of the as-is DAP was checked to confirm whether it had been modelled correctly. This involved using a case study (Yin, 2014) which was appropriate in describing events, processes, and relationships (Denscombe, 2010), to empirically verify whether the process model conformed with formal practice. Semi-structured interviews involving face-to-face interaction were used to collect data. This data collection approach accorded flexibility, such as availing respondents a chance to expound ideas (Creswell, 2014; Denscombe, 2010). Respondents were limited to only subject matter experts (SMEs) who, according to Debevoise and Geneva (2011), are individuals who know a process in detail and also have control over it.

Upon confirming the as-is DAP, the second objective was to propose a new DAP (i.e. the to-be DAP). This was accomplished by using the same process modelling method described in the preceding paragraph, albeit with minor changes. The third stage in the process modelling method was not necessary since the to-be DAP did not require empirical verification – it was non-existent in Uganda.

After designing the to-be DAP, the next objective was to demonstrate how CDM could be integrated into the to-be DAP. A case of emissions associated with a typical dwelling unit that had been approved to be constructed in Kampala was used. The dwelling was considered to be typical because its specifications, such as materials and construction techniques, matched the findings from the Uganda National Household Survey (UBOS, 2010). The cause of emissions was limited to only constructing walls, consistent with recent proposals by UNFCCC (2013b).

4. Application of the methodology

In the previous section, the methods used to achieve each of the three objectives of this study have been discussed. This section focusses on how these methods were applied to achieve each of the three objectives.

4.1. Description of the as-is DAP

The first stage of the process modelling method started with reviewing relevant regulations (Building Control Act, 2013; Environmental Impact Assessment Regulations, 1998; Physical Planning Act, 2010) in order to identify: how the process starts, what determines when it is complete, and the different ways in which it could end (Silver, 2011, p.57). In the second stage, Business Process Modelling and Notation (BPMN) grammar was used to construct the process model (see OMG, 2014; Recker & Rosemann, 2010; Silver, 2011; Takemura, 2008; Wand & Weber, 2002). In the third stage, two urban local planning authorities (Kampala Capital City Authority and Kira town council) that have the highest rates of construction activities were considered. SMEs were identified as members of a Physical Planning Committee for each authority since Physical Planning Committees are vested with powers to control the DAP (Physical Planning Act, 2010). Eight physical planning committee members were initially selected, considering four from each authority (i.e. physical planner, architect, engineer, and environmental officer). In the semi-structured interview procedure, the process model of the as-is DAP was presented to the informants who were then asked to describe how the activities shown are executed in formal practice. Discussions were recorded and later transcribed for analysis using Nvivo 10 software (Bazeley & Jackson, 2013), following a directed content analysis approach (Hsieh & Shannon, 2005). In this analysis approach, codes/themes were predefined based on the components of the as-is DAP. Words and/or phrases that supported a particular theme were identified and then coded to that theme. Results were presented by showing coding references (i.e. number of times an aspect is coded), codes with exemplars, and descriptive excerpts from interview transcripts (Hsieh & Shannon, 2005).

4.2. Designing the to-be DAP

In addressing the second objective, the first stage of the process modelling method was based on the findings from empirical verification. These findings suggested what could be done to improve the as-is DAP. A mathematical model suggested in Kibwami and Tutesigensi (2014) was used to identify new subprocesses which were used to revise the as-is DAP into the to-be DAP. In the second stage, BPMN was used to design the process model of the to-be DAP.

4.3. Integrating CDM into the to-be DAP

The demonstration case was found to have the characteristics shown in Table 1. Two options, a baseline and a 'green' alternative, were considered. In the latter option, provisions to reduce carbon emissions were included. The emission-factors of the various energy sources that were considered are presented in Table 2. For manufacture of materials in the alternative option, 60% of the energy was assumed to be sourced from non-fossil renewable energy, whereas 20% biofuel blend was assumed in all transportation activities (see Table 3). The activity of constructing the walls was assumed to be entirely carried out by human workforce without need for powered equipment. Other general assumptions which were considered are presented in Table 4. The total emissions consisted of emissions from manufacture of materials, emissions from transporting materials, and emissions from transporting workforce.

Table 1: Information about the house

Parameter	Description
Building type	Typical two-bedroom residential house
Construction technique	Traditional: masonry burnt mud bricks
Floor to wall-plate height	3m
Number of bedrooms	2No.
Number of floors	1No.
Internal floor area	103m^2
Total wall area	223m^2
Wall width (un-plastered)	0.107m (based on 228x 107 x 69mm bricks) [a]
Openings areas: Doors	21m^2
Windows	24m^2
Roof type and structure	Corrugated iron sheets on timber roof truss structure
Total cement required (walling only)	2.23Tons (assuming 0.01tons per m^2, stretcher bond) [a]
Total bricks required (walling only)	11,147 bricks (50 bricks per m^2)
Total sand required (walling only)	1 trip, 6-tonne truck
Water	excluded from the analysis

[a] source: UNFCCC (2013b)

Table 2: Emission factors for common energy sources in Uganda

Fuel/energy source	Emissions factor [a]	Conversion to MJ 1kWh=3.6MJ
Diesel (100% mineral diesel) for vehicles	0.545 $kgCO_2/km$	N/A
Diesel (electricity)	0.68 $KgCO_2/kWh$	0.189 $KgCO_2/MJ$
Heavy fuel oil (HFO) for electricity	0.71 $KgCO_2/kWh$	0.197 $KgCO_2/MJ$
Biomass	0 $kgCO_2$	N/A
Grid electricity (diesel, HFO, and Hydroelectricity mix)	0.14 $kgCO_2/kWh$	0.039 $KgCO_2/MJ$

[a] source: UNFCCC (2010)

Table 3: Proportion of energy used

Energy sources	Material (cement) manufacture		Transportation (material or workforce)	
	Base line [a]	Alternative [b]	Base line [a]	Alternative [b]
Diesel	0.35	0.10	1.00	0.80
Non-fossil	0.30	0.60	0.00	0.20
Heavy fuel oil	0.05	0.00	N/A	N/A
Electricity	0.30	0.30	N/A	N/A
Total	1.00	1.00	1.00	1.00

[a] Based on typical energy use in Uganda
[b] Based on the goal of renewable energy policy; dependence on 60% renewable energy and 20% biofuel blend in the transport sector (The Republic of Uganda, 2007).

Table 4: General assumptions

Issue	Assumption	Reference
Energy requirement for cement production	4.9 MJ/kg	Worrell, Pric, Martin, Hendriks, and Meida (2001, p.321)
Emissions from cement manufacture	46% energy-related and 54% process-related	Worrell et al. (2001, p.321)
Distance of transporting Cement to site	560 km average roundtrip (from Hima and/or Tororo cement factories)	Google Maps
Mode of transporting all materials	6-ton diesel truck	UNFCCC (2010)
Emissions from brick manufacturing	Taken as zero	Pooliyadda and Dias (2005)
Emissions from sand manufacturing	Taken as zero	Based on practices: sand is naturally occurring material that is usually unprocessed
Distance of transporting bricks and sand	50 km roundtrip	Based on construction site location: usually sourced not very far from construction sites
Mode of workforce transportation	14-passenger diesel public transportation vehicle	Based on predominantly used public transport
Emissions per person per unit distance	0.0390 $kgCO_2$	0.545$kgCO_2$/km ÷ 14
Travel distance per person per day	a 20 km roundtrip	Based on construction site location
Emissions per person per day	0.780 $kgCO_2$	0.0390$kgCO_2$ × 20 km
Total workforce	4 people (2 masons and 2 assistants)	
Quantity of wall constructed per day	3.17 m^2 per mason	Nalumansi and Mwesigye (2011)
Total construction duration	35 days	223m^2 ÷ 3.17m^2/day ÷ 2

Emissions from manufacture of materials were computed by multiplying the total energy required to manufacture a unit of material (Table 4), with the proportion of energy source used (Table 3), with the emission factor of that energy source (Table 2), and with the total quantity of material required (Table 1). For instance, considering diesel-emissions in manufacturing cement, the baseline and alternative options were computed as: 4.9 MJ/Kg × 0.35 × 0.189 $KgCO_2$/MJ × 2230 Kg = 722 $kgCO_2$ and 4.9 MJ/Kg × 0.10 × 0.189 $KgCO_2$/MJ × 2230 Kg = 207 $kgCO_2$, respectively. This calculation process was repeated for other energy sources, but with varying proportions (Table 3) of energy sources used.

Emissions from transporting materials were computed by multiplying the distance of transporting materials (Table 4), with the proportion of energy source used (Table 3), with the emissions emitted per unit distance for that energy source (Table 2). Taking an example of transporting cement, the baseline and alternative options were computed as: 560 km × 1.00 × 0.545 $kgCO_2$/km = 305 $kgCO_2$ and 560 km × 0.80 × 0.545 $kgCO_2$/km = 244 $kgCO_2$, respectively. A similar calculation was applied for bricks and sand.

Emissions from transporting workforce were computed by multiplying the emissions per person per day (Table 4), with the proportion of energy source used (Table 3), with the total workforce required for the activity (Table 4), with the total duration of the activity (Table 4). Thus the baseline and alternative options were computed as: 0.780 $kgCO_2$/person/day × 1.00 × 4 people × 35 days = 110 $kgCO_2$ and 0.780 $kgCO_2$/person/day × 0.80 × 4 people × 35 days = 88 $kgCO_2$, respectively (see Table 4).

The resulting baseline and alternative emissions were multiplied by a factor of 28,000 to reflect the annual demand of 28,000 houses required to address housing shortage in Kampala (UN-HABITAT, 2010, p.37), assuming similar dwelling units are constructed. The resulting emission reductions were then compared to those of other CDMs in Uganda that are not related to the building sector. The findings were used to propose a CDM program whose structure and operation were described.

5. Results and Discussion

This section presents and also discusses results in relation to description of the as-is DAP, description of the to-be DAP, and proposed integration of CDM into the to-be DAP.

5.1. The as-is DAP

There are three major subprocesses in the as-is DAP: (1) environmental impact assessment (EIA), (2) building project (BP), and (3) development permission (DP). The EIA subprocess started when there was a need to carry out an EIA but this depends on whether the building project falls into a category for which EIA is mandatory. The EIA subprocess starts with an activity of 'prepare brief' and is completed when the developer is informed by the authority about the decision of approval, rejection, or deferring of the project. The BP subprocess is envisaged to start when the client or developer solicits services of a consultant to work on a prospective building. It starts with 'prepare inception report' and ends with ‘building commissioned’. The need for permission to undertake a development triggers the DP subprocess. It starts with 'prepare documentation' and is complete when the applicant/developer is informed of the decision. The decision takes the following states: unconditionally granted, conditionally granted, deferred, or not granted. The unverified as-is DAP (Figure 1) consists of three pools which are loosely held together by various linkages. Each pool represents a subprocess in which there are various activities (rounded-edge boxes) connected with arrows and diamond-shaped decision gateways to show logic of flow. Activities are presented at a collapsed high-level but contain child-level activities when expanded.

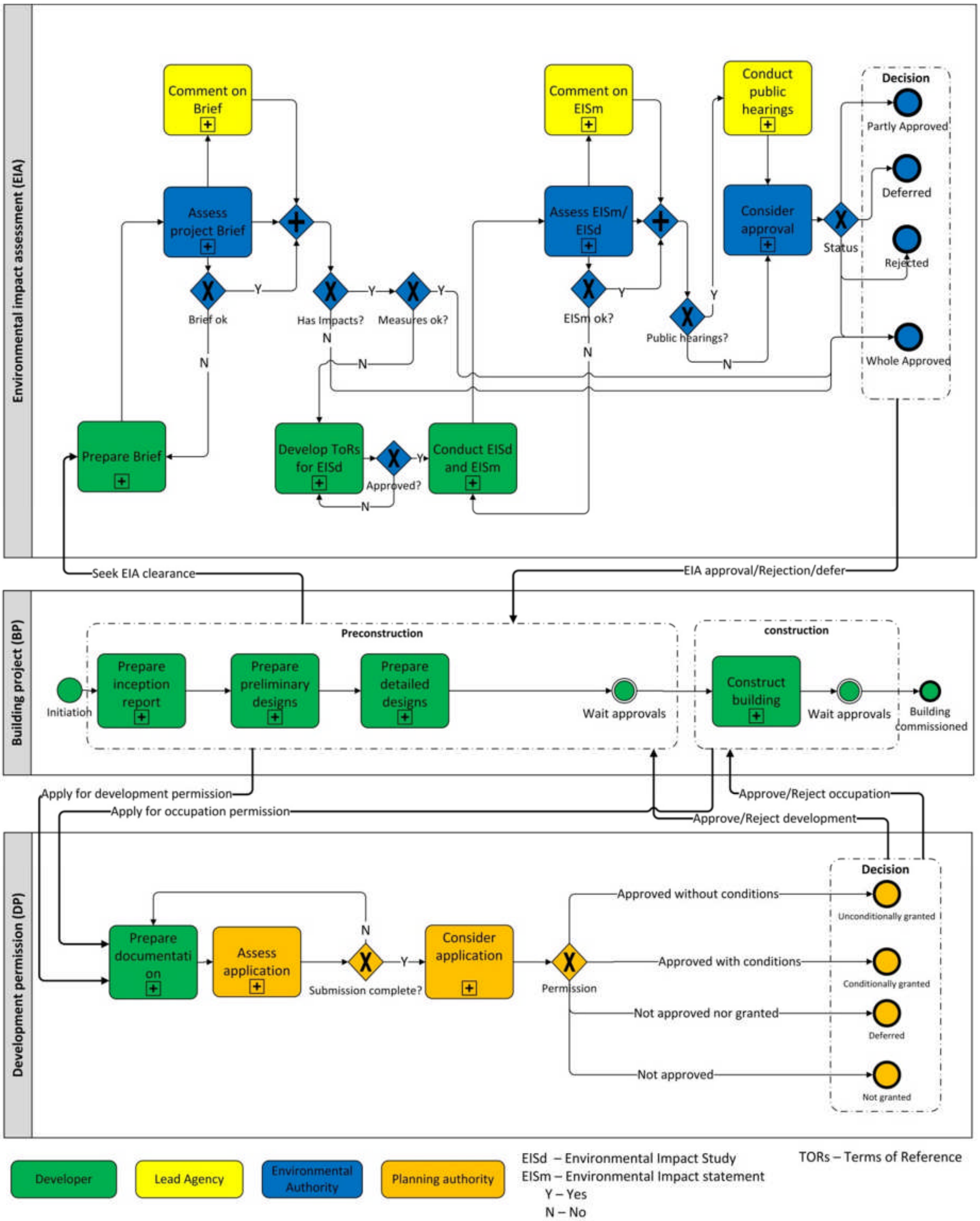

Figure 1: The unverified as-is development approval process

At the end of a two-week data-collection period, interviews each lasting about 30 minutes had successfully been conducted with: two physical planners, one engineer, one environmental officer, one health inspector, one environmentalist, and one land surveyor. Unsuccessful appointments warranted inclusion of some other SMEs who were not on the initial list. Analyses revealed that generally, all the three subprocesses had sufficiently been modelled correctly. An example of coding references and exemplars with regard to one activity/theme selected from each of the three subprocesses is shown in Table 5. The six linkages (i.e. apply for development permission, approve/reject development, seek EIA clearance, EIA approval/rejection/defer, apply for occupation permission, and approve/reject occupation) connecting the three subprocesses (see Figure 1) were also verified to be reliably accurate, since they registered coding references and exemplars. For instance: “clients bring in files through customer care, that is, we have a tent outside there” (Physical planner A) − implying application for development permission; “…we then approve the drawings and we give a client a copy, we also issue an approval letter (Physical planner B) − implying approval of development; and “…you’ve finished the structure, you [developer] have to apply for an occupation permit (Physical planner A) − implying application for occupation permit.

Table 5: Coding references and exemplars

	High-level activity		Exemplars
	Theme description	Coding ref.	
DP	Assess application (by local authority)	7	"…when you submit the drawings, we make for you an assessment […] we have acknowledged that we have received the drawings" (Physical Planner B). "The physical planner looks through to see those that meet the basic requirements for assessment" (Physical planner A). "My role there is to see adequacy of the plot, the proposed development. I check plot dimension, plot area and shape" (Land surveyor).
BP	Construction (by developer/ consultant)	6	"We don't have too much capacity to be everywhere at the right time, meaning, some construction can go on without being detected, yet they are building wrongly" (Health Inspector). "Then after approval, we have what we call a Job card, its yellow. It shows all the stages of construction of the building. So the building inspector is supposed to tick […] you call him, he signs […] so per stage you have to call him" (Physical planner A). "…we are supposed to assess after the project is complete, more especially perhaps may be when we demand for an occupation permit (Physical planner B). "If it is a storied building/ high-rise, vertical developments, there are other requirements that are needed, maybe supervision…" (Physical planner B).
EIA	Prepare Brief (by developer/ consultant)	2	"So, the way it all starts, you have to have a project brief" (Environmentalist).

Notes: DP – development permission, BP- building project, EIA – environmental impact assessment

Inspection of some variations which were identified between the initial as-is DAP and empirical observations revealed that some activities had been modelled at an aggregate level. This confirmed that regulations do not necessarily have to be prescriptive (Penny, Eaton, Bishop, & Bloomfield, 2001), implying that there can be flexibility for the practice to prescribe how to comply. Indeed, in the EIA subprocess, empirical evidence suggested that the practice is formally structured into three phases: screening, EI study, and decision-making. The verified process model of the as-is DAP took into account these finer details (refer to EIA pool in Figure 2). Similarly, observations were also noted on the linkages connecting some subprocesses. Between the BP and DP subprocesses, it was discovered that usually, the EIA subprocess is initiated in the DP subprocess but not in the BP subprocess as earlier envisaged. An environmental officer held that "once I request for an EIA, the client goes and gets a consultant who must be registered with NEMA [National Environment Management Authority]". This implied that only after making an application for building permit is the developer advised on whether EIA is required. Another identified linkage was related to payments of permit fees. When the application was assessed, the developer was notified about the amount of fees; "the clients come back, we call the clients, and they pick those plans, then they go and pay" (Physical planer A). As can be seen in Figure 2, this extra information warranted addition of two new linkages (i.e. EIA clearance/permit fees, and Permit fees/EIA certificate) that had not been initially captured. In general, most high-level activities/themes registered coding references with exemplars and no significant deviations from the formal practice were identified. It was therefore concluded that the verified as-is DAP was reliably a true representation of formal practices.

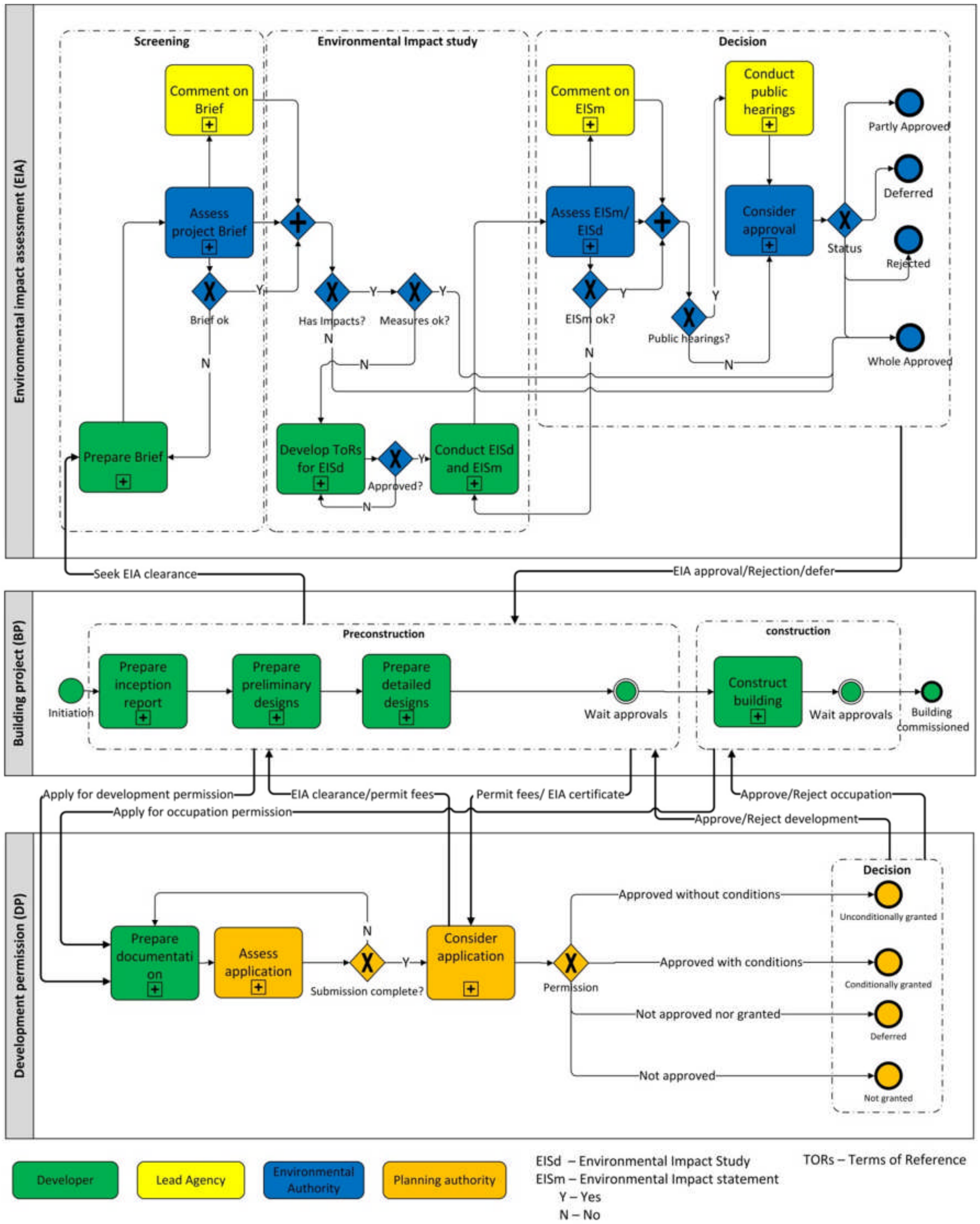

Figure 2: Verified as-is development approval process

Besides verifying that the as-is DAP had been modelled correctly, it was empirically ascertained that emissions of building projects were not considered in the assessment. This was not very surprising since consideration of carbon emissions in development approval procedures is relatively new. In developed countries such as the UK, some planning authorities have only recently started requiring developments to demonstrate how they use “materials that are sustainable and have low embodied carbon" (see Brighton and Hove, 2013, p.162). Since the basic requirement for CDM is assessment of emissions (CDM Rulebook, 2013), the lack of assessment of emissions in the as-is DAP suggested that the existing development approval procedures for buildings in Uganda were not congruent with CDM modalities.

5.2. The to-be DAP

A new subprocess of carbon accounting that was integrated in the as-is DAP led to creation of the to-be DAP (Figure 3) which was compatible with CDM. The subprocess of carbon accounting consists of one activity of 'Compute projects' emissions', entailing assessment of emissions from three aspects: construction materials, plant/equipment, and workforce (Kibwami & Tutesigensi, 2014). To take into account carbon accounting, various activities within the EIA, BP, and DP subprocesses were revised. As part of EIA, carbon accounting should be a requirement for environmental approvals. Similarly, as part of DP, carbon accounting of prospective projects was included as a requirement for issuing building and occupation permits (see "Account for carbon 1" and "Account for carbon 2" linkages in Figure 3). With regard to BP, preliminary carbon estimates can be made during early designs, detailed carbon estimates during detailed designs, and interim carbon estimates during the construction stage. By considering such aspects of carbon accounting, it could be possible to assess emissions of building projects. This potentially facilitates the integration of CDM into the DAP of buildings, as described in the next section.

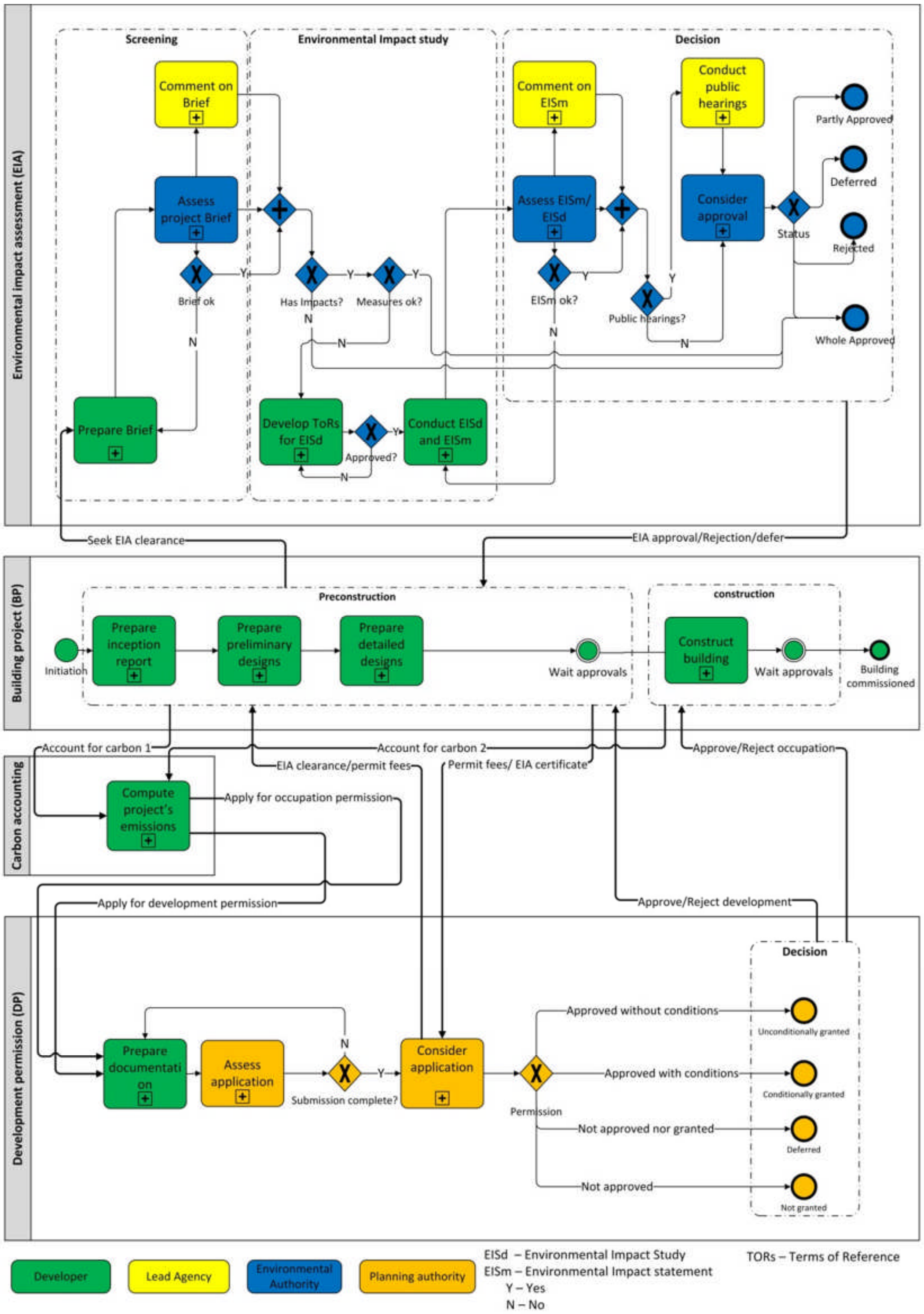

Figure 3: The to-be development approval process

5.3. Integration of CDM into the to-be DAP

The emissions associated with constructing walls of the dwelling are presented in Table 6. The total emissions for the baseline option were 2550 kgCO_2, representing 11 kgCO_2/m^2 of wall. With respect to manufacture, diesel contributed the most (75%)

energy-related emissions. The amount of emissions was highly sensitive to heavy fuel oil, as it had the highest emission factor (0.71 $kgCO_2/kWh$) amongst the fuels considered. Transportation emissions (including materials and workforce) were 18% of the total emissions, implying that at 82%, the manufacture of materials contributed the most emissions. This was not surprising since materials are known to constitute the biggest proportion of buildings' 'embodied' emissions (Chang, Ries, & Lei, 2012, p.794; Nässén, Holmberg, Wadeskog, & Nyman, 2007, p.1599; Scheuer, Keoleian, & Reppe, 2003, p.1057). For the alternative option, the total emissions were 1834 $kgCO_2$, which translated into 8 $kgCO_2/m^2$ of wall. This represented a reduction of 27% from the baseline option. The alternative option therefore demonstrates how a certain construction practice can deviate from the baseline practices (e.g. by sourcing materials from manufacturers who use renewable energy, using biofuels in transporting materials and/or workforce, etc.) in order to reduce emissions.

Table 6: Emissions from baseline and alternative options

		Baseline ($kgCO_2$)	Alternative ($kgCO_2$)
Manufacture of materials	Diesel	722	207
	Non-fossil	0	0
	Heavy Fuel Oil	108	0
	Electricity	127	127
	Non-fuel related emissions (54%)	1124	1124
	Subtotal	2081	1458
Transportation of materials	Cement	305	244
	Bricks	27	22
	Sand	27	22
	Subtotal	359	288
Transportation of workforce	Diesel-vehicle	110	88
Grand total		2550	1834

Assuming similar dwelling units are constructed in Kampala, for 2550 $kgCO_2$ per house, constructing (walls of) 28,000 houses would result into baseline emissions of 71 $ktCO_2$ (i.e. 2550 × 28000) annually. However, for the alternative 'greener' scenario, the annual emissions would be 51 $ktCO_2$ (i.e. 1834 × 28000), resulting into emission reductions of 20 $ktCO_2$ annually. If a duration of 10 years is considered, a total of 200 $ktCO_2$ would be avoided. These figures are comparable to those of other

CDMs in Uganda that are not related to the building sector (see Table 7). Therefore, creating a CDM related to building projects (BP-CDM) is possible, and considering the prevailing CDM modalities, it would be classified under small-scale types of CDM which have emission reductions of up to 60 kt per year (UNFCCC, 2014, p.40). However, as demonstrated, the initiative would require covering a substantial geographical part of Uganda whereby in this case, the whole capital city would be considered as a single CDM project.

Table 7: Some registered CDMs in Uganda and extent of emission reduction

No.	Project title and registration date	Total reductions (tCO_2eq)	Annual Reductions (tCO_2eq)	Operation period (years)	Sector [a]
1	West Nile Electrification Project (WNEP); 10th February 2007	760,417	36,210	21	E/R
2	Uganda Nile Basin Reforestation Project No.3; 21st August 2009	111,798	5,564	20	A/R
3	Bugoye 13.0 MW Run-of-River Hydropower Project; 1st January 2011	510,740	51,074	10	E/R
4	Kachung Forest Project: Afforestation on Degraded Lands; 4th April 2011	547,373	24,702	20	A/R
5	Uganda Nile Basin Reforestation Project No. 4; 29th August 2011	79,395	3,969	20	A/R
6	Bujagali Hydropower Project; 7th October 2011	6,007,211	858,173	7	E/R
7	Mpererwe Landfill Gas Project; 20th January 2012	182,612	18,261	10	W/D
8	Buseruka Mini Hydro Power Plant; 21st May 2012	314,679	31,468	10	E/R
9	Namwasa Central Forest Reserve Reforestation Initiative; 31st January 2013	226,564	11,328	20	A/R

[a] E/R - Energy industries Renewable/non-renewable, A/R - Afforestation and Reforestation, W/D - Waste handling and Disposal, BP - Building Project. Source: UNFCCC (2015)

The to-be DAP presented in Figure 3 augments the BP-CDM in various ways. Since building projects are usually geographically spread, a Programme of Activities (PoA) CDM would be appropriate. In PoA CDMs, several projects sharing similar goals can be registered as a single CDM (UNFCCC, 2014). Since the project sites in a PoA can be located in various parts of a country (Fenhann & Hinostroza, 2011), this can similarly relate to building projects. To manage the geographical spread of building projects, the existing local authorities such as districts, can be used. Each local authority (e.g. Kampala Capital City Authority) would be taken as a Component Project Activity (CPA) of the PoA. A CPA is technically defined as “a single measure, or a set of interrelated measures under a PoA, to reduce emissions or result in net removals, applied within a designated area.” (UNFCCC, 2014, p.22). In operationalising the BP-CDM, the CPAs would keep up-to-date official records (e.g. of emission factors) specific to the geographical region concerned. Upon building permit applications, baseline emissions would be assessed as per the baseline option demonstrated in this work following procedures in the to-be DAP (i.e. ‘account for carbon 1’). Alternative options such as one indicated in this work can then be considered. The investors (e.g. clients, contractors) who opt in for alternative options can then be advised of ‘greener’ choices such as which manufacturers to buy materials from. On completing construction, before issuing occupation permit, a reassessment could be done (i.e. ‘account for carbon 2’), and the extent of deviations from the baseline revealed. If positive (i.e. emissions reduced), a check can be carried out to assess where the emission reductions were achieved (e.g. whether manufacturer, contractor, client or workforce) in order to apportion incentives appropriately.

The operation of the BP-CDM (Figure 4) can be structured into three levels (developed and developing country, enabling framework, and emissions reduction and benefits), each with various actors and responsibilities. In the top level, the developed country offers technical capacity and funds to implement a 'green' solution and in return, receives CERs from the developing country. Technical capacity and funds are extended to the CPAs (see middle level in Figure 4) which also extend the same to the implementers of the green solution, who might be manufacturers or building projects. When manufacturers supply 'green' materials to the building project, they receive revenue. If manufacturers have obtained funds from the CPAs in order to manufacture ‘green’ materials, they can be tasked to offer the materials at lower competitive prices. But, if manufacturers do not claim funds from CPAs, and therefore sell materials at premium prices, the building projects could then redeem the premium from the CPAs. With such incentives, manufacturers can be motivated to innovate greener solutions since the demand will be available. For building projects, this could prompt stakeholders to adopt practices that are less carbon intensive. In so doing, this could translate into a market-based mechanism of promoting practices that enhance sustainable construction, whilst advancing the goals of renewable energy policy.

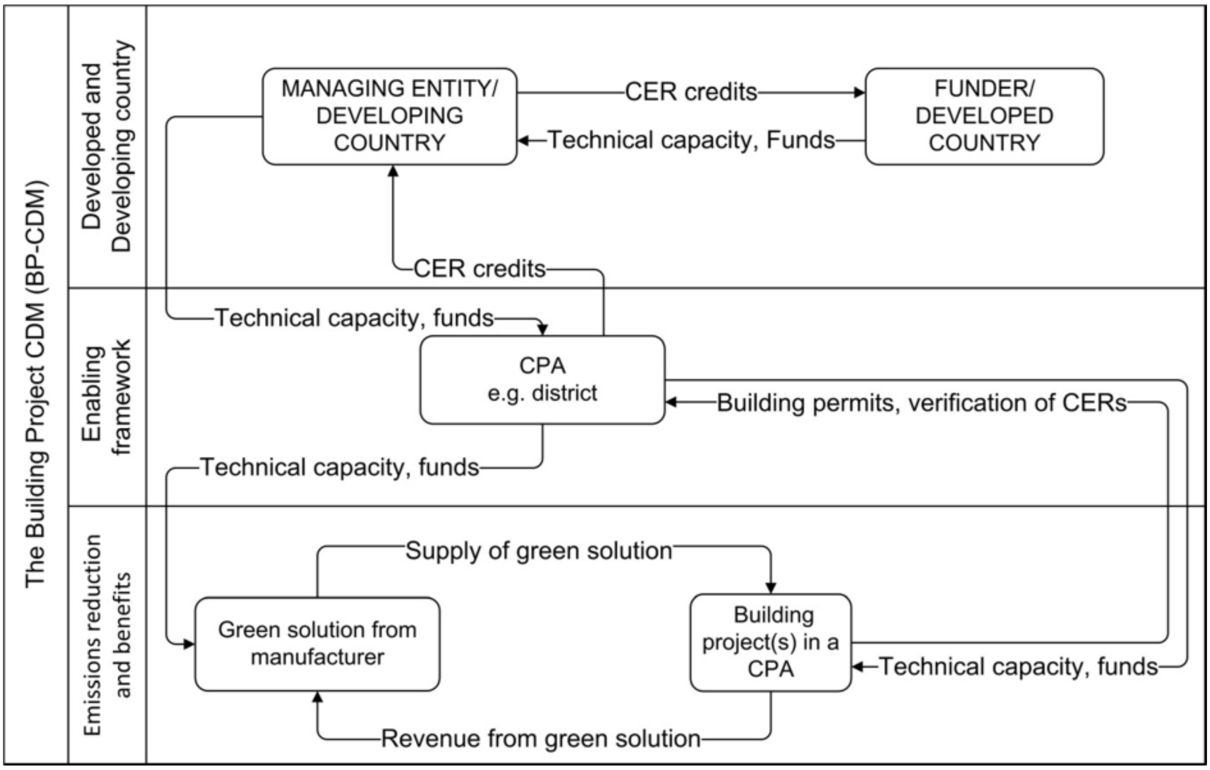

Figure 4: Suggested structure of the CDM related to buildings

6. Conclusions

It is becoming evident that only if concerted efforts are undertaken to reduce carbon emissions could the challenge of climate change be tackled effectively. The clean development mechanism (CDM) scheme is one of such concerted efforts. In recent research, the building sector, which accounts for a significant proportion of the global emissions, has been identified as suitable beneficiary of the CDM scheme. However, there is limited evidence on how this scheme can be integrated into the development approval process (DAP), wherein, the potential for emissions reduction in buildings is greatest. An investigation on integrating CDM into the DAP of buildings in Uganda has been carried out in this paper. The focus was limited to urban areas due to the much needed efforts of shrinking the persistent urban housing shortage, sustainably. An as-is DAP which describes the existing practices was derived using process modelling. The findings suggested that carbon accounting was not considered in the existing practices and therefore the as-is DAP was not compatible with CDM. A to-be DAP which considers carbon accounting, hence compatible with CDM, was designed. A demonstration was conducted on how CDM could be integrated into the to-be DAP. This involved computing carbon emission resulting from constructing a typical dwelling unit in Kampala City, based on a business-as-usual and an alternative option with provisions to reduce emissions. Findings suggested that 20 $ktCO_2$ of emissions could be avoided annually within Kampala City if CDM was integrated into the to-be DAP. Proposals on the structure of a suitable CDM program were also presented and discussed. If environmental policymakers were to take this study seriously, addressing the urban housing deficit in Uganda, and developing countries alike, could be done in more sustainable manner. That said, it would be fruitful to pursue further research about the most carbon intensive construction materials and processes used in Uganda in order to provide comprehensive databases that facilitate carbon accounting. A plausible way of achieving this is by conducting a pilot program of the proposals presented in this paper. This will enable engagement of various stakeholders such as funders, ministries, local authorities, manufacturers, and built environment professionals, to assess the practicality of the proposals.

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