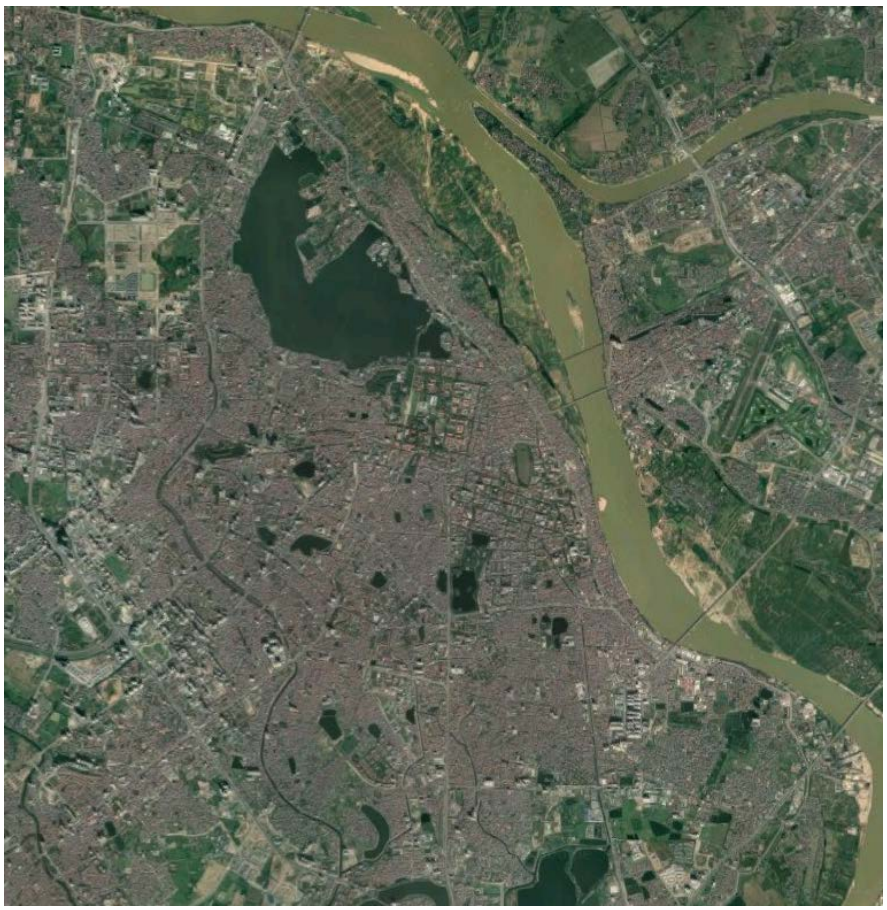
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Vietnam – Hanoi city material flows

Minerals and Waste Programme

Internal Report OR/18/068



BRITISH GEOLOGICAL SURVEY

MINERALS AND WASTE PROGRAMME

INTERNAL REPORT OR/18/068

Vietnam – Hanoi city material flows

T.P. Bide, T.J. Brown, E. Petavratzi and J.M. Mankelow

Keywords

Raw materials, urban growth, materials flow analysis, construction materials.

Front cover

Satellite imagery of Hanoi.

Bibliographical reference

BIDE, T.P., BROWN, T.J., PETAVRATZI, E. AND MANKELOW J.M. 2017. Vietnam – Hanoi city material flows. *British Geological Survey Internal Report*, OR/18/068. 49pp.

Keyworth, Nottingham British Geological Survey 2018

BRITISH GEOLOGICAL SURVEY

The full range of our publications is available from BGS shops at Nottingham, Edinburgh, London and Cardiff (Welsh publications only) see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications, including maps, for consultation.

We publish an annual catalogue of our maps and other publications; this catalogue is available online or from any of the BGS shops.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as basic research projects. It also undertakes programmes of technical aid in geology in developing countries.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

BGS Central Enquiries Desk

Tel 0115 936 3143 Fax 0115 936 3276
email enquiries@bgs.ac.uk

Environmental Science Centre, Keyworth, Nottingham NG12 5GG

Tel 0115 936 3241 Fax 0115 936 3488
email sales@bgs.ac.uk

The Lyell Centre, Research Avenue South, Edinburgh EH14 4AP

Tel 0131 667 1000 Fax 0131 668 2683
email scotsales@bgs.ac.uk

Natural History Museum, Cromwell Road, London SW7 5BD

Tel 020 7589 4090 Fax 020 7584 8270
Tel 020 7942 5344/45 email bgslondon@bgs.ac.uk

Cardiff University, Main Building, Park Place, Cardiff CF10 3AT

Tel 029 2167 4280 Fax 029 2052 1963

Maclean Building, Crowmarsh Gifford, Wallingford OX10 8BB

Tel 01491 838800 Fax 01491 692345

Geological Survey of Northern Ireland, Department of Enterprise, Trade & Investment, Dundonald House, Upper Newtownards Road, Ballymiscaw, Belfast, BT4 3SB

Tel 028 9038 8462 Fax 028 9038 8461
www.bgs.ac.uk/gsni/

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU

Tel 01793 411500 Fax 01793 411501
www.nerc.ac.uk

UK Research and Innovation, Polaris House, Swindon SN2 1FL

Tel 01793 444000
www.ukri.org

Website www.bgs.ac.uk
Shop online at www.geologyshop.com

Contents

FIGURES

TABLES

Summary

This report describes the first phase of research for a minerals materials flow analysis in an Asian Megacity. This consists of a scoping study to assess the feasibility of conducting material flow analysis (MFA) for Hanoi, with a particular focus on assessing the availability of required data. The availability of data on the production, trade, consumption, and demand for construction-related mineral commodities at a national, regional and city level within Vietnam was assessed. Although current levels of publically available data are insufficient to allow a full MFA analysis we present the results obtained from a preliminary analysis of material supply and demand in Hanoi. Supply and demand scenarios up to 2030 for several commodities important for the construction sector have been evaluated. Recommendations are also made for future application of MFA in Hanoi.

This research was supported by BGS NC-ODA grant NE/R000069/1 entitled Geoscience for Sustainable Futures. It was delivered via the BGS Asian Cities Official Development Assistance (ODA) Research Platform.

1 Introduction

Since the late 1980s, Vietnam has experienced significant economic growth due to market reforms; such growth has transformed the country from a “low income economy” to a “low middle income economy” (as defined by the World Bank) (World Bank, 2018a, b; World Bank Data Team, 2016). Economic growth has also been linked directly to rapid urban development (Arouri et al., 2017) and the associated demands for housing, infrastructure, energy, water, and waste management. All of these strands of growth increase the demand for raw materials and in the context of this study, minerals.

From about 20 per cent in 1990, the percentage of Vietnam’s population living in urban areas increased to approximately 35 per cent in 2016 (General Statistics Office of Vietnam (GSOV), 2018). It is projected that 50 per cent of the total population will live in cities by 2050 (UNEP, 2017). In order to accommodate a rising urban population, there are currently ambitious plans for additional urban development of Hanoi (Iwata, 2007; Leducq and Scarwell, 2018). Such urban development will require considerable quantities of raw materials. Meeting such demand in a rapidly urbanising economy, however, will also need to be achieved while minimising negative effects on the environment.

Between 2008 and 2016, the production of aggregates within Vietnam increased by 23 per cent, from 410 billion tonnes to 503 billion tonnes (General Statistics Office of Vietnam (GSOV), 2018). Construction aggregates in the form of crushed rock and sand and gravel are required for the production of cement, concrete, fill material and in road construction. In addition to aggregate, steel, timber and bricks are also required for the construction of buildings along with a wide spectrum of other metals and industrial minerals, which are necessary for specific construction applications (for example, copper in cables, gypsum in plasterboard and many more). An even wider range of minerals is essential for the manufacture of products that become indicative of improving standards of living.

If flows of such raw materials are constrained, then economic growth and a country’s development can be adversely affected. A restricted supply of construction raw materials during periods of high demand mean they can become prohibitively expensive, resulting in delays or cancelation of projects. Likewise, the mineral-based feedstocks necessary for manufacturing and industry may also become restricted with a resulting detrimental impact on economic growth. Constrained supply of raw materials can also lead to illegal mining operations in order to fulfil demand which can, in turn, cause great harm to the environment (Dung, 2011). There is evidence that all these effects are currently occurring in Vietnam where the rapid economic growth and recent urban expansion are causing a strain on raw material supply (Cafef, 2017; Viet Nam News, 2017a; Vietnam News Agency, 2017; Vietnamnet, 2017). In addition, many neighbouring countries, such as Malaysia and Indonesia, are also following similar trajectories for continued economic growth and urban development, which requires access to raw materials. Sometimes these materials are sourced from other countries, thereby compounding supply issues within the source country. Competition for raw materials in South East Asia is unavoidable. With it comes the risk of supply disruption if planning for access and use of raw material flows and stocks does not take place. This is not only an issue of concern at national level, is also a concern at the region and city levels.

The effects of supply shortages have already made an appearance in Vietnam. Sand prices rose by up to 100 per cent in 2017, believed to be due to supply restrictions related to the enforcement of environmental restrictions and a clampdown on illegal mining (Viet Nam News, 2017b). For example, sand mining in the northern provinces of Bac Ninh and Ba Giang has been suspended until an inspection of operations is completed. This is causing significant issues in construction project development as contracts have been agreed on lower prices and insufficient amounts of material are now coming onto the market. Likewise in June 2017, prices for sand were reported to have risen by 40 per cent for major road construction projects because of a shortfall in required

volumes (Vietnamnet, 2017). A report in August 2017 from the ministry of construction states that prices increased from between 50 per cent and 200 per cent between March and April. By the end of March the price for sand for concrete in Hanoi rose to 200–300 thousand VND per cubic metre (Vietnam.net, 2017).

The Greater Hanoi area is set for rapid urban expansion over the next 10-20 years with the city developing a major new road network, new rail links, an expanded core, five satellite urban areas and three eco townships (Perkins Eastman, 2011). To meet these ambitious targets large quantities of raw materials are required. It is within the context of this planned urban development and the associated increasing demand for raw material supply that the current research has been undertaken. The research consisted of a scoping study to assess the feasibility of conducting a material flow analysis (MFA) for Hanoi, with a particular focus on assessing the availability of required data. The availability of data on the production, trade, consumption, and demand for construction-related mineral commodities at a national, regional and city level within Vietnam was assessed. Although current levels of publically available data are insufficient to allow a full MFA analysis we present the results obtained from a preliminary analysis of material supply and demand in Hanoi. Supply and demand scenarios up to 2030 for several commodities important for the construction sector have been evaluated. Recommendations are also made for future application for MFA in Hanoi.

2 Objectives of the research project

This project attempted to quantify the demand for construction materials required for urban development in Hanoi, Vietnam. The questions that the present research explored are:

1. What are the construction material requirements in Hanoi to meet the predicted urban expansion?
2. What are the implications of the future material demand requirements?

Answers to the above questions can be obtained by understanding how construction materials flow through society, from initial extraction (source) to the end-of-life. This type of information facilitates better planning and decision making for the use of raw materials in terms of balancing supply with demand and ensuring no bottlenecks are present between source and end user. It also enables planning for sustainable production and consumption of raw materials. Such an analysis requires data on material production and trade, consumption and stocks that ideally would be at a city or regional level if the case study of Hanoi is to be considered. Therefore, the first stage of this research was to assess the availability of relevant data to see if an analysis of flows of construction materials on a city level was feasible, and if not what analysis could be undertaken and conclusions drawn by utilising the available data.

Due to their essential role in urban development, this research has focused primarily on materials required for construction. In addition, it was important to ensure that good quality data can be collated at the scale required to ensure that an analysis of the demand for construction materials in Hanoi can take place.

In detail the objectives of this project were:

1. To investigate the urban development plans for Hanoi and the demand requirements for construction materials.
2. To identify the availability of data on production and consumption of construction materials for the city of Hanoi.
3. To quantify the demand for construction materials required for new building and infrastructure projects in Hanoi at present and in the future.
4. To develop material flow analysis models for specified construction materials for the city of Hanoi.

5. To investigate the implications of the demand for construction materials given the urbanisation plans for Hanoi. These may include issues around security of supply for construction materials, environmental implications associated with increasing mining activities, social issues, economic implications, technological barriers and so on. These are expected to become apparent as the project progresses further.

The research project will be completed over multiple phases. The current report presents the results from phase 1.

3 Project approach

3.1 THE PROJECT SCOPE

The questions outlined in section 2 are the starting point of this project. In order to develop a methodology that can provide sufficient answers, additional clarifications to these questions have to be given. This can be achieved by following a method developed by the EU H2020 MICA project on the "Integration of data, methods and expert knowledge to inform mineral intelligence" (Van der Voet, 2017).

Questions 1 and 2 are assessed individually and flowsheets are produced that provide a pathway to reaching a valuable answer. An overview of the key system components and the boundaries of the analysis is provided in Figure 1.

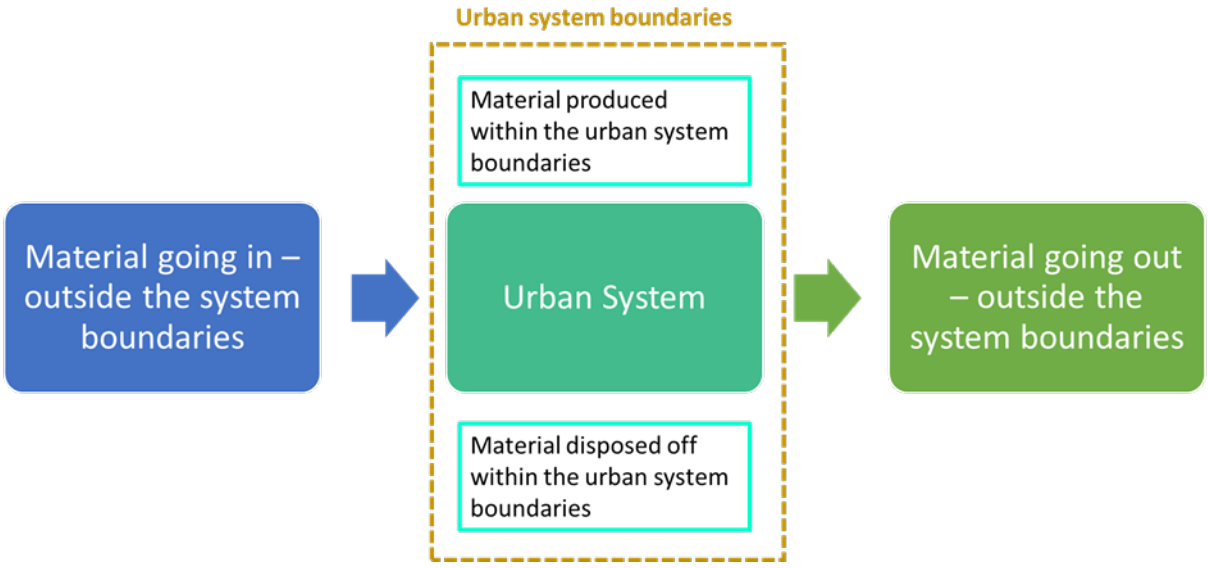


Figure 1: Overview of system components and boundaries.

Question 1: What are the construction material requirements in Hanoi to meet the predicted urban expansion?

The first step in this method requires the translation of the principal question into a series of refined questions. To do so the boundary conditions of Question 1 are first identified.

Table 1: Boundary conditions of Question 1.

Boundary category	**Boundary condition**
Commodities	Construction materials
Process chain (activity)	Mining and quarrying; material/product manufacture
Impacts	Economic

Spatial (activity)	City level (Hanoi)
Spatial (impact)	The spatial impacts of the urban expansion in Hanoi and the demand for materials may be at city, regional and national level
Temporal (activity)	Future – investigating future urban development impacts
Temporal (impact)	Future
Flows and stocks	Import, export, production, consumption

When assessing the information given by the initial principal question, it becomes clear that uncertainties about the commodities to be included in the analysis and the time horizon to be considered exist. In addition, the question asks for an assessment of construction materials supply and demand and an investigation of the urban growth foreseen for Hanoi. Question 1 can be broken down into sub questions that frame the scope of this project better and enable the development of a methodological approach. The suggested sub-questions are:

1.1 What construction materials are used in Hanoi and in what applications? Of these, what are the commodities included in this research and what are the construction projects considered in the analysis?
1.2 What are the historic trends of construction materials use in Hanoi?
1.3 What urban expansion is foreseen in Hanoi? Are there any forecasts for the urban growth in Hanoi?
1.4 What is the time horizon considered in this project?

Sub-questions 1.1 and 1.2 require an assessment of the availability of data on construction materials at city, regional and national level and an investigation of the construction material consumption trends in Hanoi. Answers to sub-questions 1.1 and 1.2 can be provided by exploring the national statistics on construction minerals.

Sub-question 1.3 requires the assessment of relevant information and data related to urban planning. As a starting point, answers to this question can be provided by desk-based research. Depending however on data availability, stakeholder engagement with urban planners in Vietnam and researchers in Vietnam involved in this subject can provide additional insight.

Sub-question 1.4 requires determining the time horizon of the analysis. This is driven initially by data availability.

There are different ways to answer Question 1 depending primarily on data availability. The flowsheets in Figure 2, Figure 3 and Figure 5 summarise three approaches that provide in detail the data (squares) and methods (yellow circles or mathematical symbols) that are required to reach an answer. These are:

- Top-down approach to quantifying supply and demand (Figure 2).

This includes the calculation of future supply (left hand side) based on mineral production trends and population growth trends and forecasts. The calculation of future demand (right hand side), projects apparent consumption figures based on forecasted population growth. The top-down approach is based solely on material flows and population statistics and does not take into account urban growth plans, building stock information etc. In that sense, it is much more ‘simplistic’ than the other two approaches presented below.

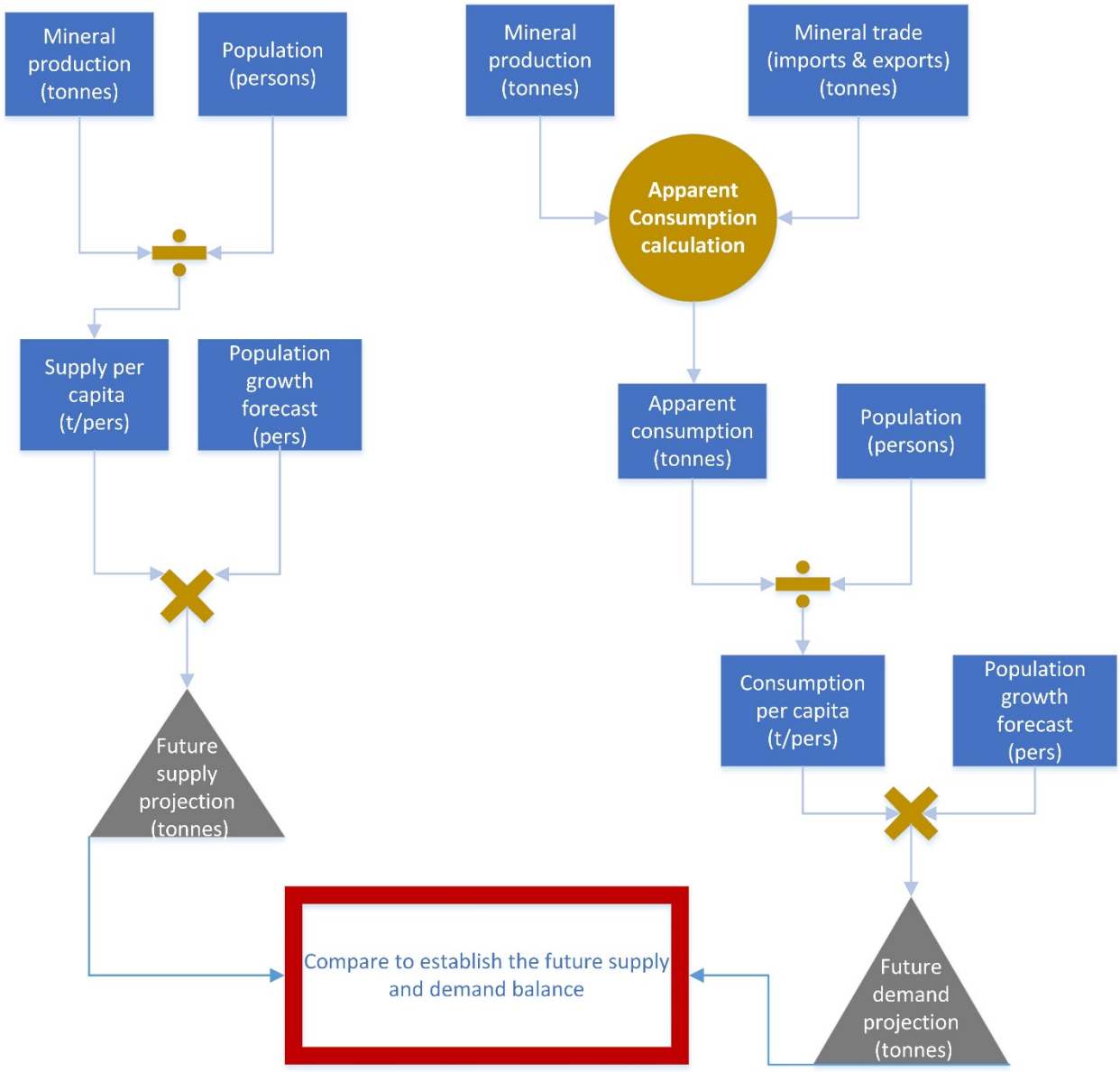


Figure 2: Schematic diagram explaining the steps involved in the top-down future supply and demand balance calculation.

- Bottom-up approach to quantifying supply and demand (Figure 3).

Using this approach, the future supply calculation is the same as for the top-down approach in that it is based on mineral production data and projections of population growth. The future demand calculation quantifies material demand in new building stock and it requires information related to building types in Vietnam - building compositions and building floor area information from urban planning documents. This is a much more detailed approach to quantifying material requirements for new construction. It requires access to data that are not readily available for Hanoi, for example the material composition of average buildings in Vietnam, as well as extensive knowledge of how urban planning will evolve in the city of Hanoi, not just in terms of land use (where some data is available), but also with regards to changes in building and construction.

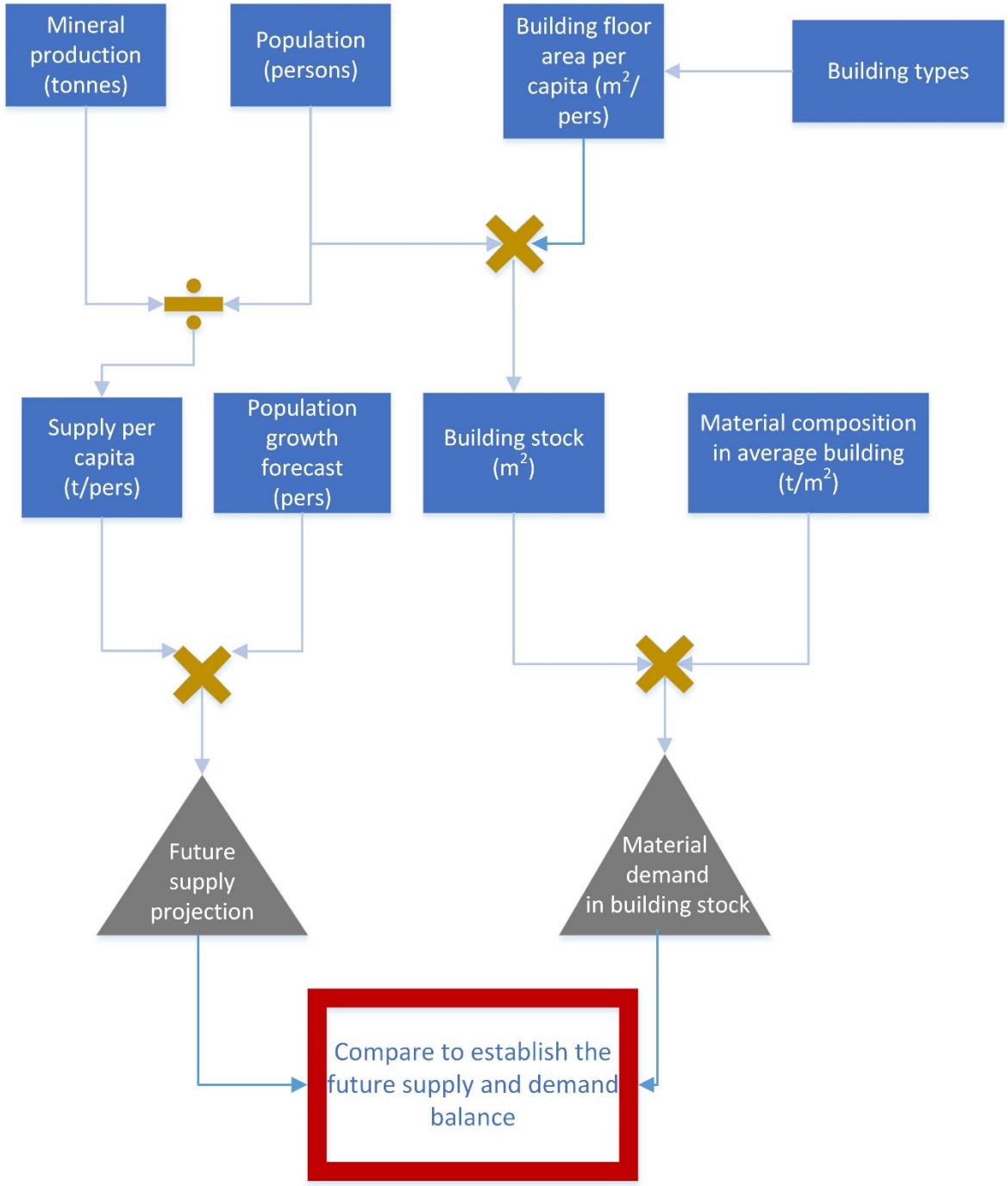


Figure 3: Schematic diagram explaining the steps involved in the bottom-up future supply and demand calculation.

- Dynamic material flow analysis (MFA) of construction minerals in Hanoi

The dynamic material flow analysis comprises the best approach to obtain an answer to Question 1, as it allows for detailed quantification of the flows and stocks of construction materials in Hanoi. The simplified system describing the construction minerals cycle in Figure 4 presents some of the key flows and stocks available that require quantification to develop a material flow analysis. One of the first steps to be completed for developing a dynamic MFA model is the development of a system describing the Hanoi construction minerals cycle in detail. This requires in depth understanding of the construction sector in Vietnam as well as engagement with stakeholders from Hanoi, ranging from representatives of the construction and extraction industries to urban planners and policymakers. A dynamic model has the time dimension embedded in the analysis. It is possible therefore to evaluate how material flows and stocks change over time, both in past, present but also for predicting future material supply and demand (Figure 5). The dynamic MFA approach is much more detailed and data intensive than either of the top-down or bottom-up approaches, but at the same time it allows better forecast predictions to be made and supply disruption issues to be identified for the city of Hanoi; thus facilitating better informed interventions tailored to resolving specific supply disruption issues. The model could assist the Vietnamese government and Hanoi local authorities to make informed decisions about urban development without material related constraints and also to respond to potential challenges by having access to good supportive information.

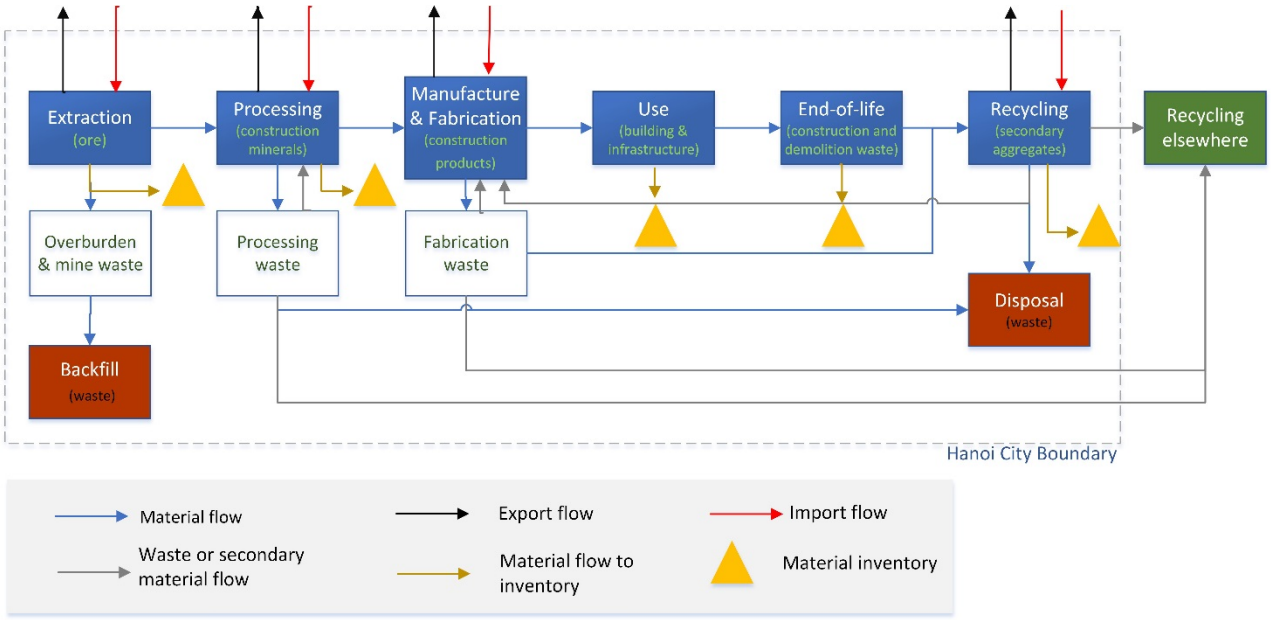


Figure 4: Simplified system of the construction minerals cycle.

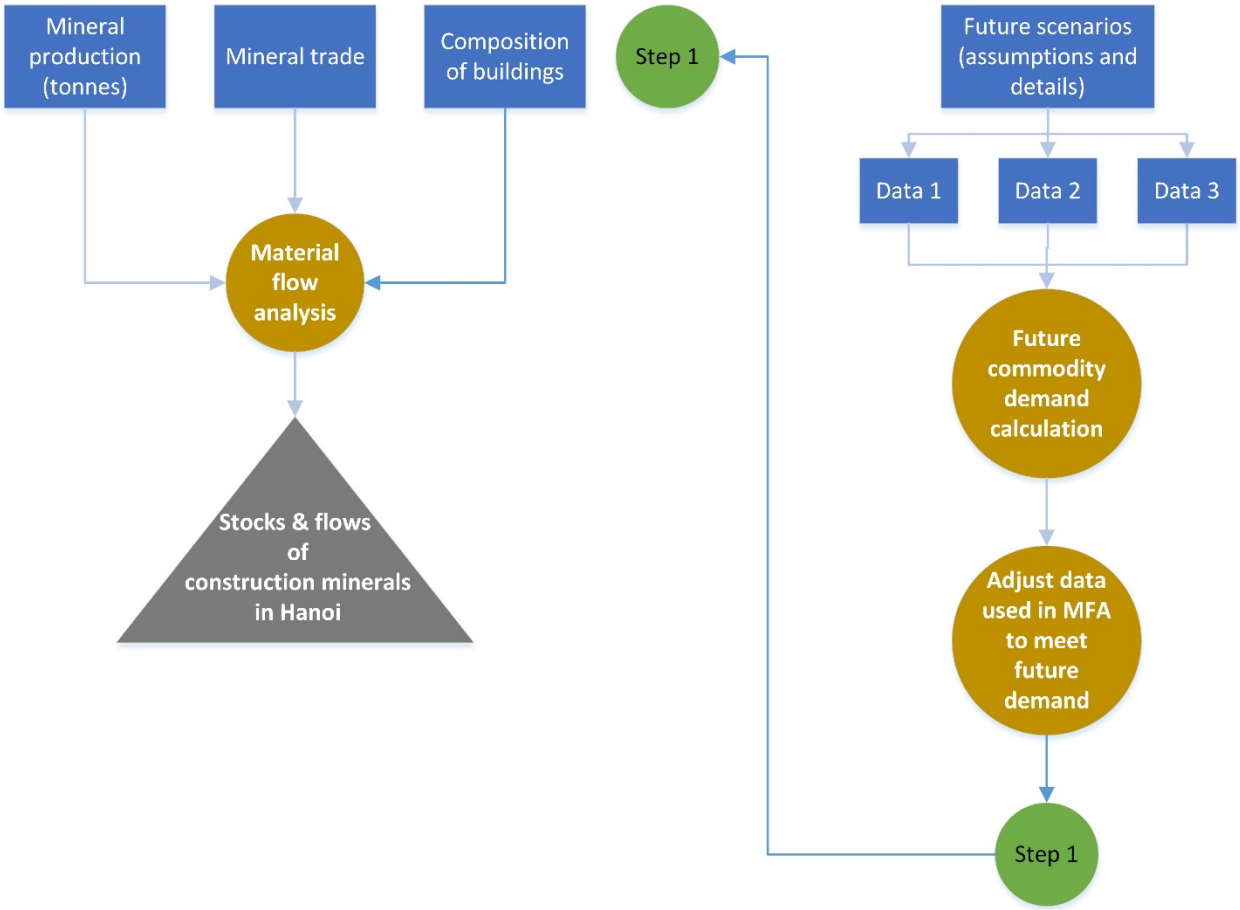


Figure 5: Schematic diagram explaining the steps involved in using dynamic material flow analysis to forecast future demand of construction materials in Hanoi.

Question 2: What are the implications of the future material demand requirements?

This follows from Question 1 and asks to identify the implications (if any) associated with future material demand. The implications may vary widely, for example, an increase in demand may lead to environmental impacts and health and safety issues due to intensive mining activities, or illegal mining and trade of construction minerals. Supply disruption due to constrained access to raw materials may result in increased prices for materials, a slowdown of construction projects and urban development, and an overall reduction of economic growth.

The boundary conditions of Question 2 are the same as Question 1. Answers to this question can be provided through two different routes:

- Qualitative assessment of the overall impacts of future material demand through desk based research and stakeholder engagement.
- Quantitative assessment of selected impacts attempting to develop an additional 'layer' in the material flow model. This will require extensive data gathering through engagement with Vietnam stakeholders, i.e. those listed in Appendix 2.

This report only represents a preliminary study of the material status in the city of Hanoi. It provides a top-down quantification of supply and demand and a qualitative assessment of the potential implications associated with growing material demand. A detailed investigation of data availability and gaps has been undertaken to support the present assessment and inform the future steps of this project.

4 Urban development in Hanoi

Hanoi is located in the northern Vietnam, in the Red River delta, approximately 90km from the coast. In recent decades Hanoi has undergone significant transformation and rapid expansion has led to the achievement of the international metropolitan status (Leducq and Scarwell, 2018), as well as this a change in the official city boundary in 2008 has substantially increased the size of the city. Since the Doi Moi policy (1986), increased globalisation and the significant development observed in neighbouring countries in South East Asia has meant that Hanoi has entered a new era of expansion with plans in place to increase the metropolitan area to 3300 km^2. The Hanoi planning strategy is described in the Hanoi Master Plan 2030-2050 document. The urban plan follows similar trends observed in many cities worldwide and is based on an urban cluster model adopted by many Asian cities (Leducq and Scarwell, 2018). In brief, the plan includes the following (JICA and Hanoi People's Committee, 2007; Leducq and Scarwell, 2018; Trihamdani et al., 2017):

- An urban core, extended to include additional neighbouring provinces.
- Five satellite cities with a population range between 130,000 to 600,000 inhabitants. These include the Hoa Lac (science and technology urban centre), Son Tay (focus on culture and tourism), Soc Son (focus on industry and tourism), Xuan Mai, Phu Xuyen.
- Three eco township/villages that include Phuc Tho, Quoc Oai and Chuc Son.
- An extensive urban network system consisting of highways, express ways and park ways, plus an urban railway network (high speed railway and metro) that connects all major development areas between them and with the urban core, and which also provides connections with the rest of the country.
- A green belt to serve the purpose of environmental and agricultural conservation. This is going to be developed on the west of the current urban core.
- A blue corridor with flood management areas.
- An upgrade of existing urban areas to improve living standards, preserve the cultural heritage and promote economic growth.

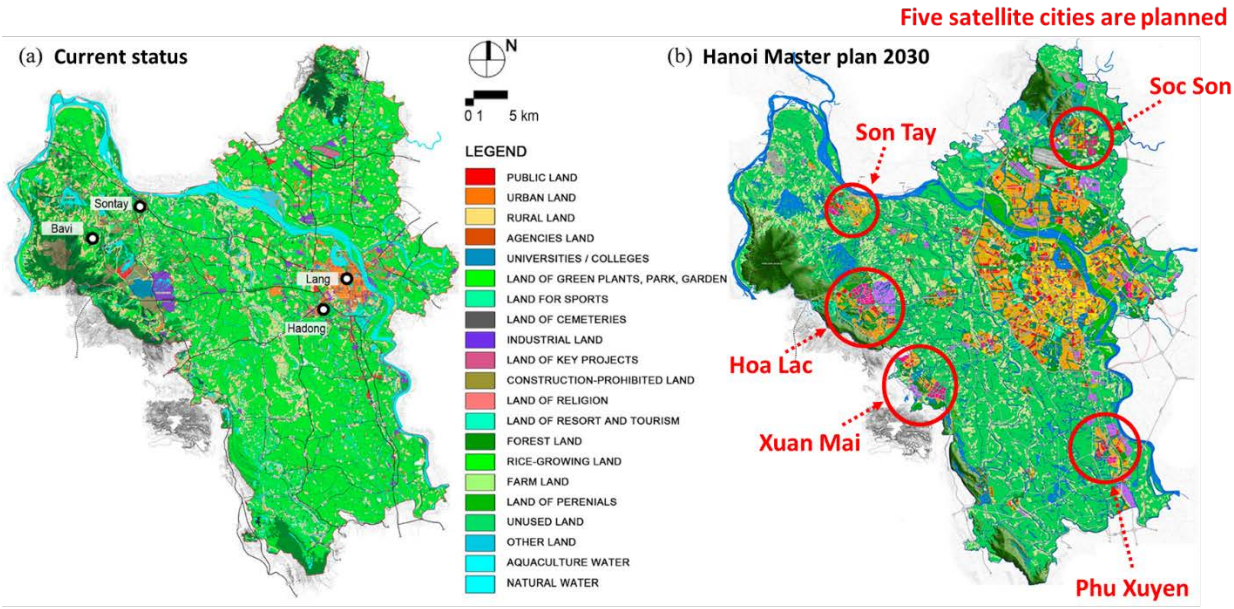


Figure 6: Current and future plans of urban development in Hanoi (Trihamdani et al., 2017).

Several challenges have been identified by previous research regarding the urban expansion plans in Hanoi. These are important and may obstruct future development in Hanoi. They include (JICA and Hanoi People's Committee, 2007; Leducq and Scarwell, 2018):

- Impacts to water management: installation of formal drainage networks is not keeping pace with urban expansion to the urbanisation growth and the risks for flooding are therefore higher. In addition existing issues associated with clogged irrigation channels and unequal access to irrigation for agriculture add to the impact.
- Governance issues due to the extended size of the Hanoi territory. Several stakeholders and multi-party planning policies are involved, including an increasing number of private companies who are responsible for managing urban development projects in Hanoi.
- Transport issues associated with traffic and road congestion are increasing. These are attributed to urban growth, which pose pressures on transport infrastructure and have led to the development of a new 'Transport plan to 2030, with a vision to 2050'. The Transport Plan gives priority to public transport and it includes a new highway network and a new metro with an urban rail of 8 lines and a total length of about 318km.
- Hanoi is experiencing a construction boom in order to accommodate the continuously increasing urban population. A shift to the development of high-rise buildings is already apparent with around 20 skyscrapers already in place and more than 10 currently under construction. In addition, more than 700 real estate projects have been given permits, often comprising semi-detached or detached houses that do not resemble the style of old apartments and the typical three to five storey tube houses. Meeting the demand for material required to support the construction work taking place is challenging and if not managed well may lead to negative impacts on the environment, affect social cohesion, limit economic development and increase the potential for supply disruption.
- Land use issues and pressures on agricultural land. These originate from the transformation of land from agricultural to urban use, the rate of transformation and the way that this takes place.
- Concerns over the metropolitan land use plans that may be compromised by the growing urban economy.
- Changes in the social dimension of Hanoi's metabolism associated with the demographic transformation, the land use changes, cultural changes associated with urbanisation, and the development of new technology and industry hubs to support economic growth. These will require access to more resources (e.g. material, water, energy, food) and management of the social (e.g. living standard expectations) and environmental aspects (e.g. waste and water management, air pollution) of the urban transformation.

5 Data availability

The first phase of this work involved identifying data sources that could be used to conduct material flow analysis or supply and demand analysis at a national/regional/city level in Vietnam. This is a necessary step in both assessing at what resolution the analysis can be conducted and to identify significant data gaps.

A wide range of data types were considered before focusing on minerals and especially construction minerals. The most useful datasets identified were:

- Mineral production
- Trade (imports and exports)
- Consumption of mineral resources
- Land use
- Population changes

Other data, which may be useful included:

- Recycling rates of construction materials
- Price data

- Construction activity
- Mineral resources and reserves

5.1 DATA AVAILABLE FOR VIETNAM FROM INTERNATIONAL SOURCES

5.1.1 BGS World Mineral Production

BGS compiles annual data for mineral production by country worldwide for more than 70 mineral commodities. Long time series are available with records for many commodities going back over 100 years. Data is compiled on an annual basis by BGS from a wide range of sources: home and overseas government departments, national statistical offices, specialist commodity authorities, company reports, and a network of contacts throughout the world. The latest data is for 2016 which was published in February 2018; for most of this scoping study the most recent year available was 2015. Data can be downloaded from here:

http://www.bgs.ac.uk/mineralsuk/statistics/worldStatistics.html and is available in an internal BGS database, which has been queried to produce tables in Appendix 1.

5.1.2 USGS minerals data

Similar to BGS the USGS also publish data, both commodity and country specific, on an annual basis, worldwide. This consists of production data, a brief commentary about the country's mineral industry and a list of operating minerals companies. The most recent factsheet for Vietnam is for 2014 and is located here: https://minerals.usgs.gov/minerals/pubs/country/2014/myb3-2014-vn.pdf

5.1.3 UN commodity trade data

The UN provide a free-to-access data portal for global trade data, which is accessible at: https://comtrade.un.org/. Data is compiled nationally, on an annual basis from statistics reported by individual countries. Data for individual mineral commodities, in terms of value and tonnage, can be extracted. Some data can be confidential and the latest is reliant on when it was provided by the reporting country. The most recent data for Vietnam currently is for 2015. There are also no data available for quantities for aggregate minerals for Vietnam, only values in US$. Data are also missing for some years for iron and steel trade however, data could possibly be reconstructed by analysing exports from the world to Vietnam and imports to the world from Vietnam.

5.1.4 World Bureau of Metal Statistics

This is a small, commercial organisation that compiles annual statistics for predominantly non-ferrous metals but a few other metals too. BGS has access to their monthly reports containing data on production, trade and consumption on a national basis and is available for 1-2 months behind the current date. The reports are stored on the BGS's Electronic Record Management System (ERMS). Some of the production data are incorporated into the BGS World Mineral Production data, but this source also contains consumption statistics compiled on a national level. The WBMS holds the IPR for these figures and permission would need to be sought if they were to be used.

5.2 DATA AVAILABLE WITHIN VIETNAM

5.2.1 National scale data

Data for Vietnam seems difficult to find. This is most likely due to a combination of a language barrier and the lack of an apparent streamlined reporting structure. There are several government departments which have extensive websites, such as the ministry of construction (http://www.xaydung.gov.vn/en/trang-vat-lieu-xay-dung) or the general department of Geology

and Minerals of Vietnam (DGMV) (http://dgmv.gov.vn/index.php?lang=vi), but little in the way of data applicable to material flow analysis. The latter website does have some information on illegal river sand mining, which although does not contain any figures, is an indicator of the supply issues facing Vietnam. The General Statistics Office of Vietnam (discussed in more detail below; http://www.gso.gov.vn) also has a range of national data, such as industrial products and imports and exports by theme. However, these are mostly indexed so may be of limited use. The Statistics Office does have some statistics for mineral production, including sand and gravel, on a national level (but not for all minerals) together with other data that can be used as proxies for demand.

There are also several bodies representing the minerals and construction sector in Vietnam that have no information published on their respective websites but may be useful contacts. These include: the cement producers trade association of Vietnam (http://www.vnca.org.vn/vn/) and the Vietnamese association for building materials (http://hoivlxdvn.org.vn).

Specifically regarding sand and gravel, there are also numerous news articles on illegal mining and the issues it is causing in Vietnam and in the Red River Delta around Hanoi (for links see Appendix 3). These articles can contain information on prices, supply and demand suggesting that figures on construction material supply and demand are available for Vietnam, however data does not seem to be readily available on the internet. One article presents data sourced from the Department of Construction Materials, however nothing appears available on the Department's website. The same article also quotes the Head of the Construction Material Division stating that provinces are not permitted to sell or transfer sand to other provinces, indicating that there may be no official data for the movement (flow) of this particular construction material from one province to another within the country because in theory it does not occur.

5.2.2 Regional data

Some regional data can be obtained from the General Statistics Office of Vietnam relating to, for example, land use or population. Much of these data are also available at 'province' level for which Hanoi can be separated out specifically (see below). However, statistics for the number of new houses constructed are only available by region (e.g. the Red River Delta region) rather than for individual cities.

5.2.3 City level

There appears to be little in the way of statistics specifically regarding minerals supply to Hanoi. However, there are some data available from the General Statistics Office of Vietnam which can be used as proxies for material demand. For example, under the land and climate statistics section data for land use are available and the change from agricultural to housing may give an indication of the increases in development and consequently the demand for construction materials. Similarly, under the population and employment statistics section there are data for change in population density by province, which could potentially act as a proxy for construction material demand.

Under the transport statistical data section there are data for volume of freight by province (in thousand tonnes) and this would be very useful for materials flow analysis. However, these data do not differentiate between different freight types (so is likely to be dominated by non-mineral goods). Furthermore, it is not clear whether the tonnages are recorded at the source or destination.

There is a separate department of construction for Hanoi City (http://www.soxaydung.hanoi.gov.vn/vi-vn) and this website does have some price information for construction materials but no other data.

5.3 SUMMARY

Table 2 Summary of data availability.

Vietnam	Data Type				
	Production	Trade	Consumption/ demand	Reserves/ resources	Other relevant data
National	Yes, from DGMV, statistics office and BGS	Yes/partial UN Comtrade only has values for many commodities	No	No	Statistics Office has indexed data for trade and industrial growth, some data for sand and gravel is in specific news articles.
Regional	No	No	Not directly	No	The Statistics Office has some data that may be used as a proxy for material demand/ consumption.
City	No	No	No	No	Price data is available from The Department of Construction for Hanoi.

5.4 DATA GAPS IDENTIFIED

- There are no publically available city level data for material production or flows for Hanoi. Some regional data on demand and production may be useful as a proxy for the city level but there are no data that can be used as a proxy for the flow of material into a city.
- There are gaps in national trade data reported by Vietnam for the mass of certain materials traded.
- There are no data on material flows on a regional level for Vietnam.
- There are several publications which are referenced on various websites which could be of great use but are not available publically on the internet. These include:
    - Statistics from the Department of Construction of Vietnam (these are referenced in various news articles but do not appear on the Departments website)
    - Statistics from the Vietnamese cement producers association (these are referenced in various news articles but do not appear on the associations website)
- Due to illegal mining it is possible that any flow data between administrate boundaries (if available) and production data for sand and gravel extraction may be under reported.
- There are very little data regarding secondary resources apart from a few mentions of recycled aggregates in news articles and peer reviewed literature for Vietnam.

6 Data for land use, population and housing

The website for the General Statistics Office for Vietnam (GSOV) includes a number of datasets relating to land use, population and housing. This part of the scoping study examined the content and resolution of these datasets to see which ones were available at city scale (as opposed to regional or national scale) and to determine whether they could be combined together in a useful way to inform calculations for material demand and/or supply. Past trends in statistics can also be used to inform projections for future demand and supply scenarios.

6.1.1 Land use

The GSOV website includes a dataset for ‘Land use by province’ which includes area figures in thousand hectares divided between different categories. These figures are available for the whole country, for regions (e.g. Red River Delta) and at city level (e.g. Hanoi) and it is assumed these figures represent the area of land currently in use for the different purposes specified at the given

date. However, the specified sub-categories do not sum to the 'total area' column (see). In addition, the meaning behind some of the sub-category descriptions are not clear, e.g. 'Specially used land'.

Table 3: Land use by province and cities (as of 31 December 2015). Unit: Thousand hectares.

	Total Area	Agricultural production land	Forestry land	Specially used land	Homestead land	Sum of 4 sub-categories	Difference to Total Area
Whole country	33 123.1	11 530.2	14 923.6	1 839.2	698.6	28 991.6	4 141.5
Red River Delta	2 126.0	799.0	494.4	313.8	143.9	1 751.1	374.9
Hanoi	335.9	157.1	22.3	62.8	40.1	282.3	53.6

In an attempt to clarify the headings, a series of tables entitled "Land Use Survey 2000" was consulted on the GSOV website. These tables were only available in Vietnamese and translated using Google Translate. The main headings were shown as: Agricultural land, Forestry land with forests, Specialised land, Landscape and Unused land with rivers and rocky mountains. There was no category for homestead land.

Within the heading of 'specialised land', the sub-categories were land for construction, transport, irrigation, historical relics, security and defence, exploiting minerals, brick and tile, making salt, cemetery and 'other'. This seems to suggest that it is primarily industrial uses but there are other industrial uses that would seem to be missing, such as manufacturing factories. The 'landscape' category was further divided into 'urban' and 'rural' which is confusing because the agricultural and forestry land is also presumably 'rural' while many industrial processes would typically take place in an 'urban' setting.

Because there is no correlation between other studies on the website and the data shown in Table 3, further information from the GSOV or other contacts in Vietnam is required before this dataset could be used.

6.1.2 Population

The GSOV website includes several datasets relating to population numbers, the split between 'urban' and 'rural' population, and population density. Figure 7 shows the annual population numbers for Vietnam with a split between urban and rural residents. The growth in the urban population is clearly seen (and amounts to 114 per cent between 1995 and 2016) while the numbers of rural Vietnamese residents has levelled off (the increase is only 6 per cent between 1995 and 2016). The population of Hanoi is also shown in this figure for comparison purposes. In 2016 the city contained 8 per cent of the total Vietnam population although population has grown by 55 per cent between 1995 and 2016.

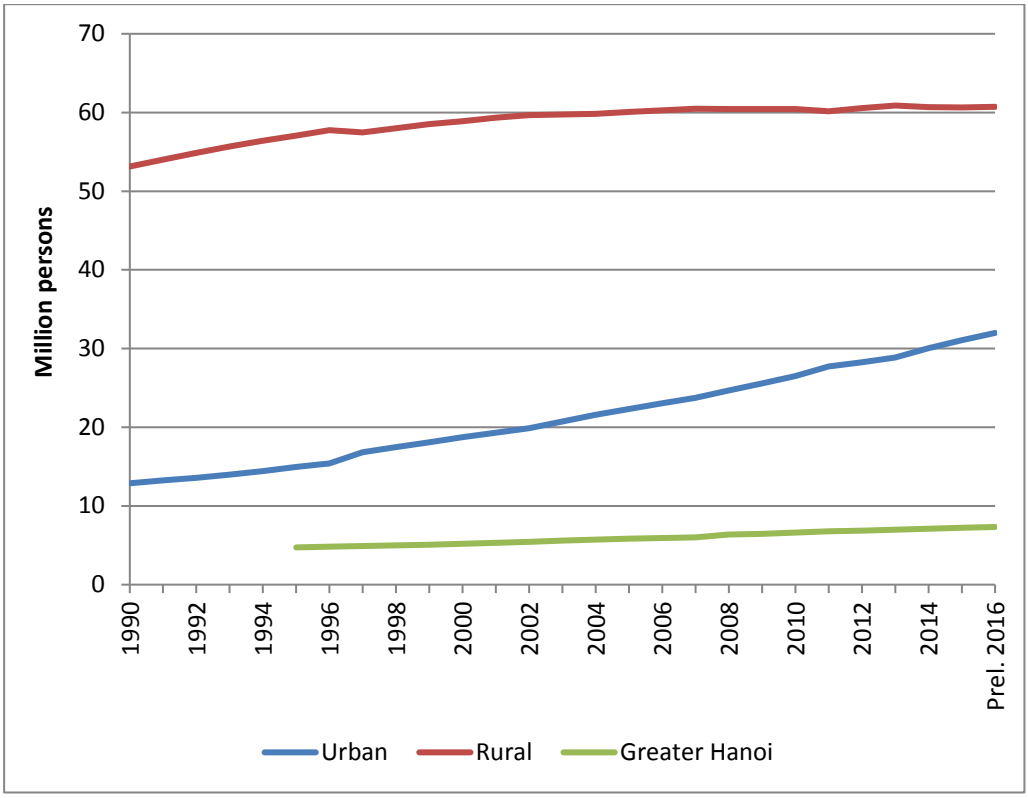


Figure 7: Population numbers in Vietnam split between urban and rural areas; population numbers for Hanoi are also shown for comparison. Data sourced from GSOV.

Interestingly, Hanoi is not the fastest growing city/province in Vietnam (Figure 8) and in terms of overall numbers Hanoi has been overtaken by Ho Chi Minh City (Figure 9).

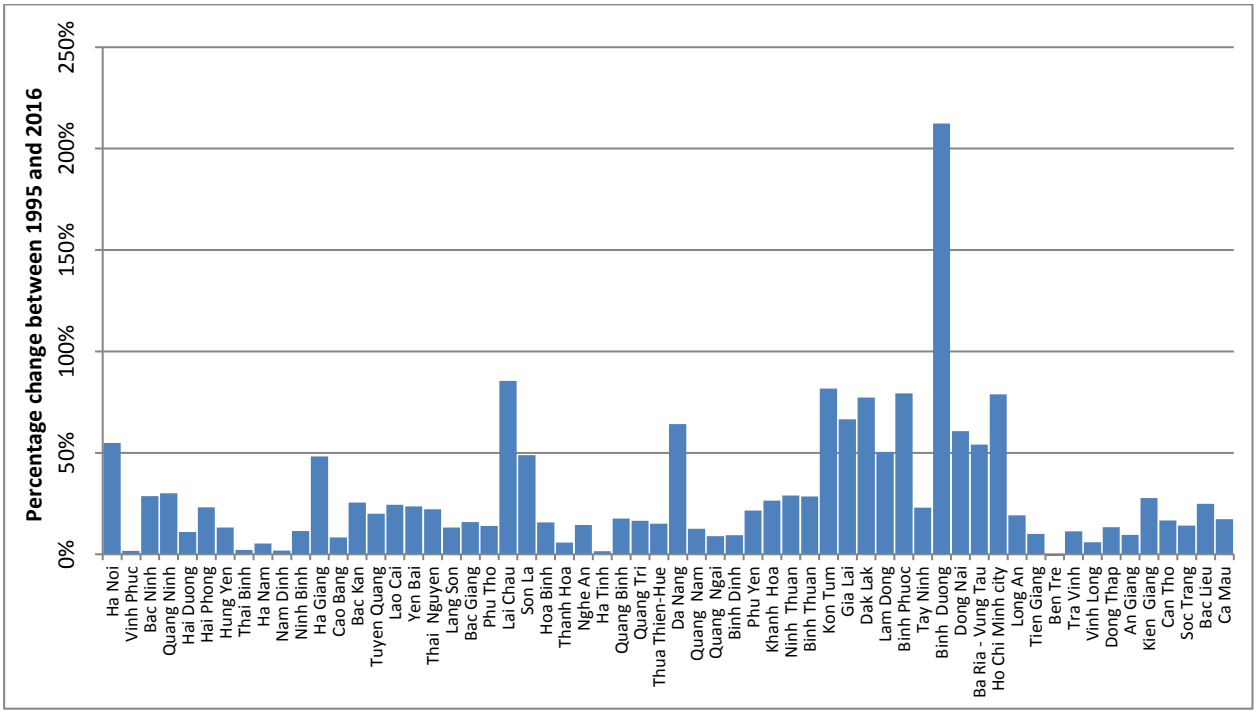


Figure 8: Population growth between 1995 and 2016 by city or province in Vietnam. Data sourced from GSOV.

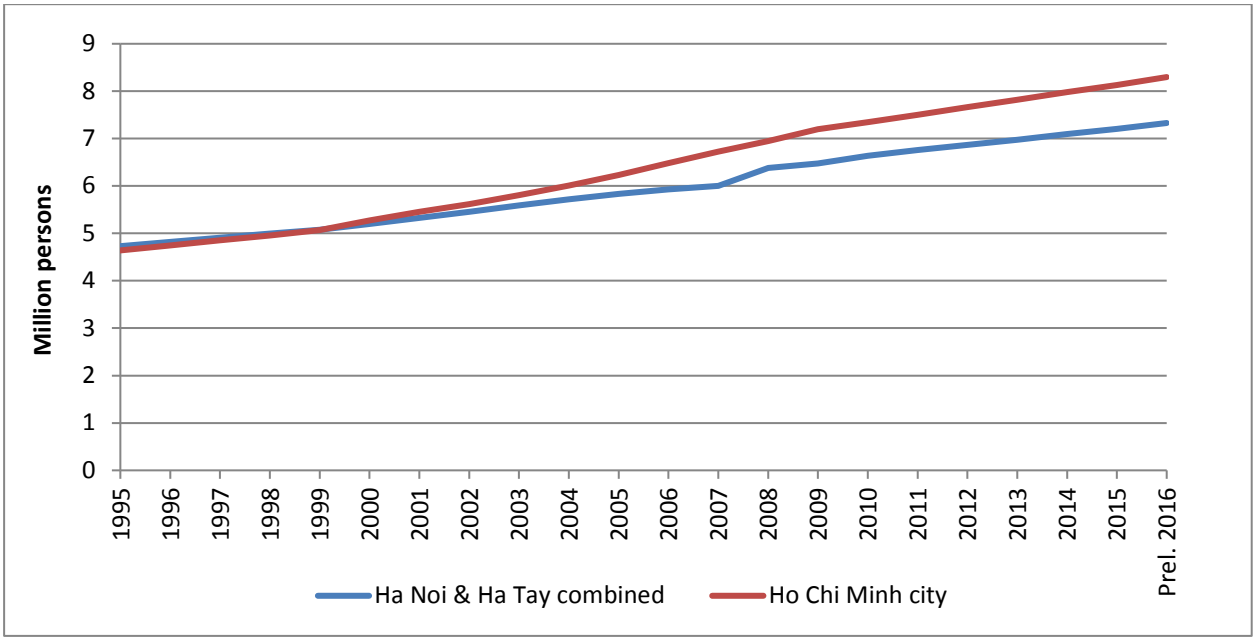
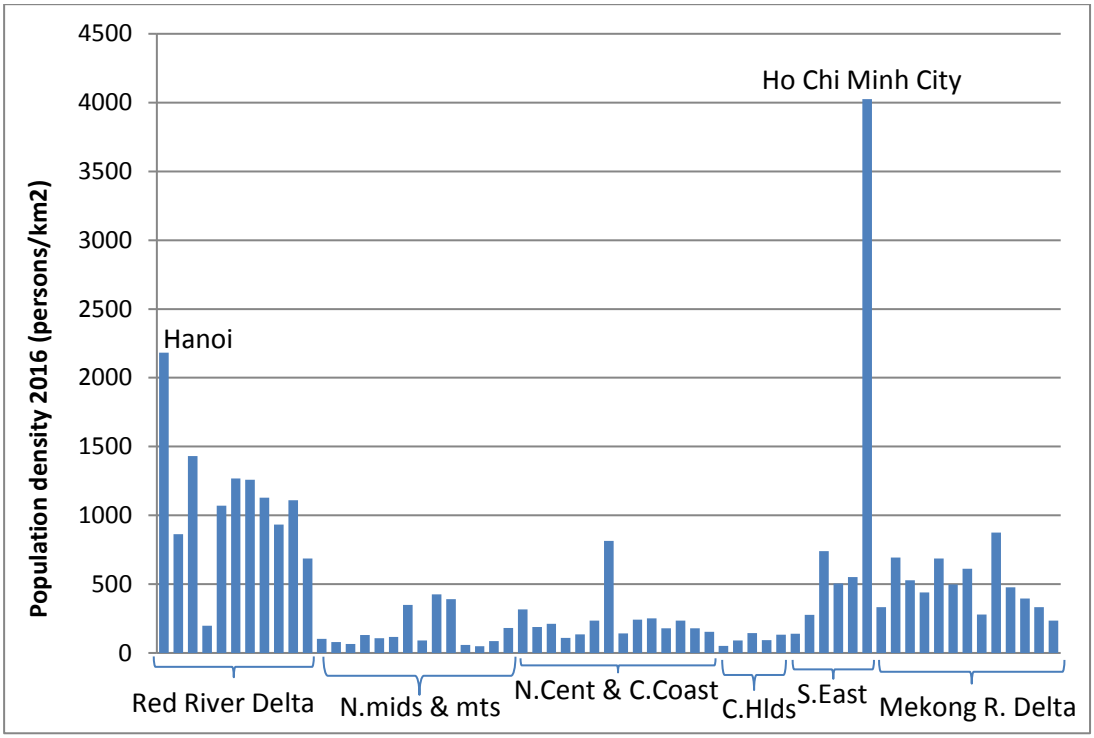


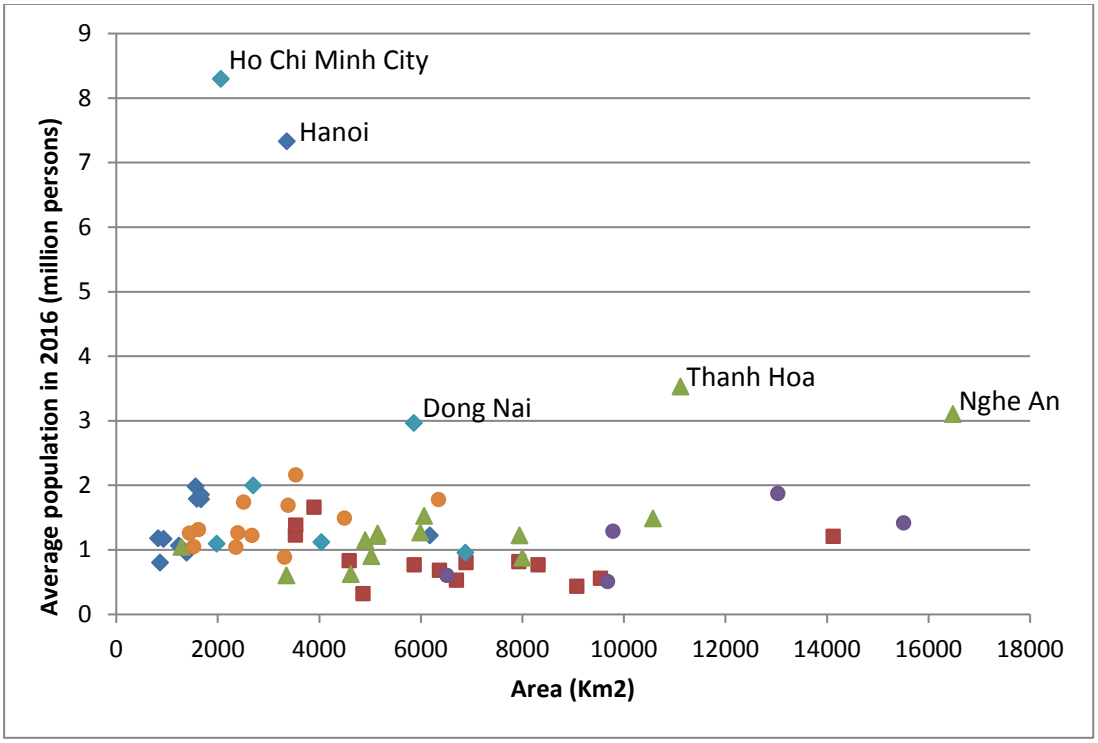
Figure 9: Population numbers in Hanoi and Ho Chi Minh City from 1995 to 2016. Data sourced from GSOV.

With regards to population density, this can easily be calculated by dividing the number of persons by the area, but this is actually unnecessary because the GSOV website also provides these figures in table format. It is not surprising to find that Hanoi and Ho Chi Minh are the two most densely populated parts of Vietnam, but in reality Ho Chi Minh has a population density that is almost double that of Hanoi (Figure 10), Hanoi and Ha Tay have been combined to take into account the 2008 boundary change expanding Hanoi). Plotting population numbers against areas of cities and provinces clearly shows the population density of these two major cities. The next three largest cities/provinces in terms of population have larger surface areas (Figure 11).



Note: The individual provinces and cities are clustered by Region in Figure 10. "N.mids & mts" is Northern Midlands and Mountain Areas; "N.Cent & C.Coast" is Northern Central and Central Coastal Areas; "C.Hlds" is Central Highlands; "S.East" is South East; "Mekong R.Delta" is Mekong River Delta.

Figure 10: Population density by city or province in Vietnam in 2016. Data sourced from GSOV.



Note: Darker blue diamonds are Red River Delta region; red squares are Northern Midlands and Mountain Areas; green triangles are the Northern Central and Central Coastal Areas; purple circles are the Central Highlands region; paler blue diamonds are the South East region; and orange circles are the Mekong River Delta region.

Figure 11: A plot of average population by area for each city and province in Vietnam in 2016. Data sourced from GSOV.

6.1.3 Housing

The GSOV website includes data for the quantity of housing floors constructed by region in each year and also some details of the types of housing that people are occupying at city and province scale.

All regions have seen increases in the quantity of 'housing floors' constructed per year in the period from 2007 to 2015 (Figure 12). The largest increase is in the Central Highlands where the quantity of housing constructed in 2015 was 122 per cent higher than in 2007. The Northern Midlands and Mountain Areas region was close behind with 118 per cent, followed by the Mekong River Delta with 110 per cent and the North Central and Central Coastal areas with 103 per cent. Hanoi is located in the Red River Delta region which saw the lowest comparative figure of 48 per cent. Ho Chi Minh is located in the South East region which had the second lowest figure of 49 per cent. These figures, however, do hide some variation from year to year as seen in **Figure 12** and overall a greater quantity of housing floors was constructed in the Red River Delta region than in other regions in every year apart from 2008 and therefore the greatest demand for construction materials for housing.

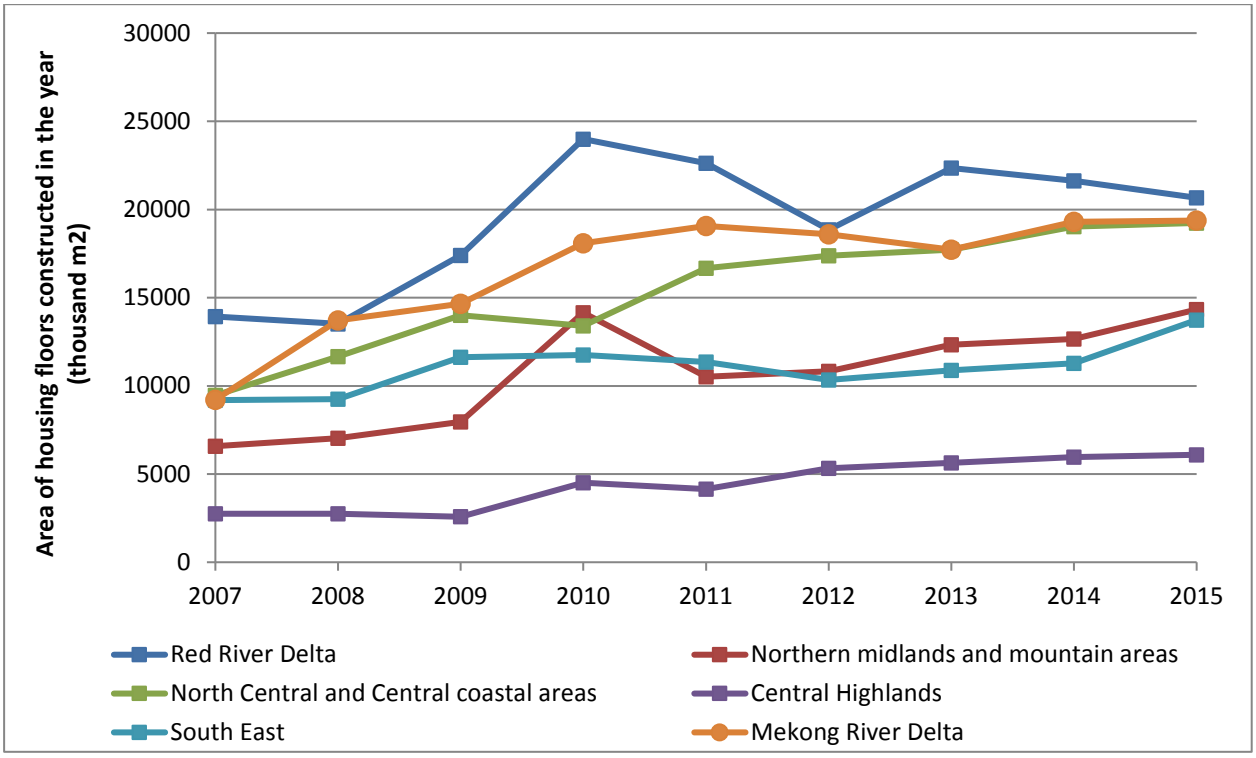


Figure 12: Quantity of housing floors constructed per year by regions of Vietnam. Data sourced from GSOV.

Looking at the data for types of housing, the GSOV figures are divided into four categories: 'permanent house', 'semi-permanent house', 'less-temporary house' and 'simple permanent house'. The precise definitions behind these terms are unknown but Figure 13 shows that the region with the highest percentage of households living in a 'permanent house' is the Red River Delta region (92.9 per cent of households), including Hanoi. In contrast, the Mekong River Delta has the lowest proportion of households with permanent houses (9.2 per cent of households) and the South East region, including Ho Chi Minh, is not much higher (18 per cent of households).

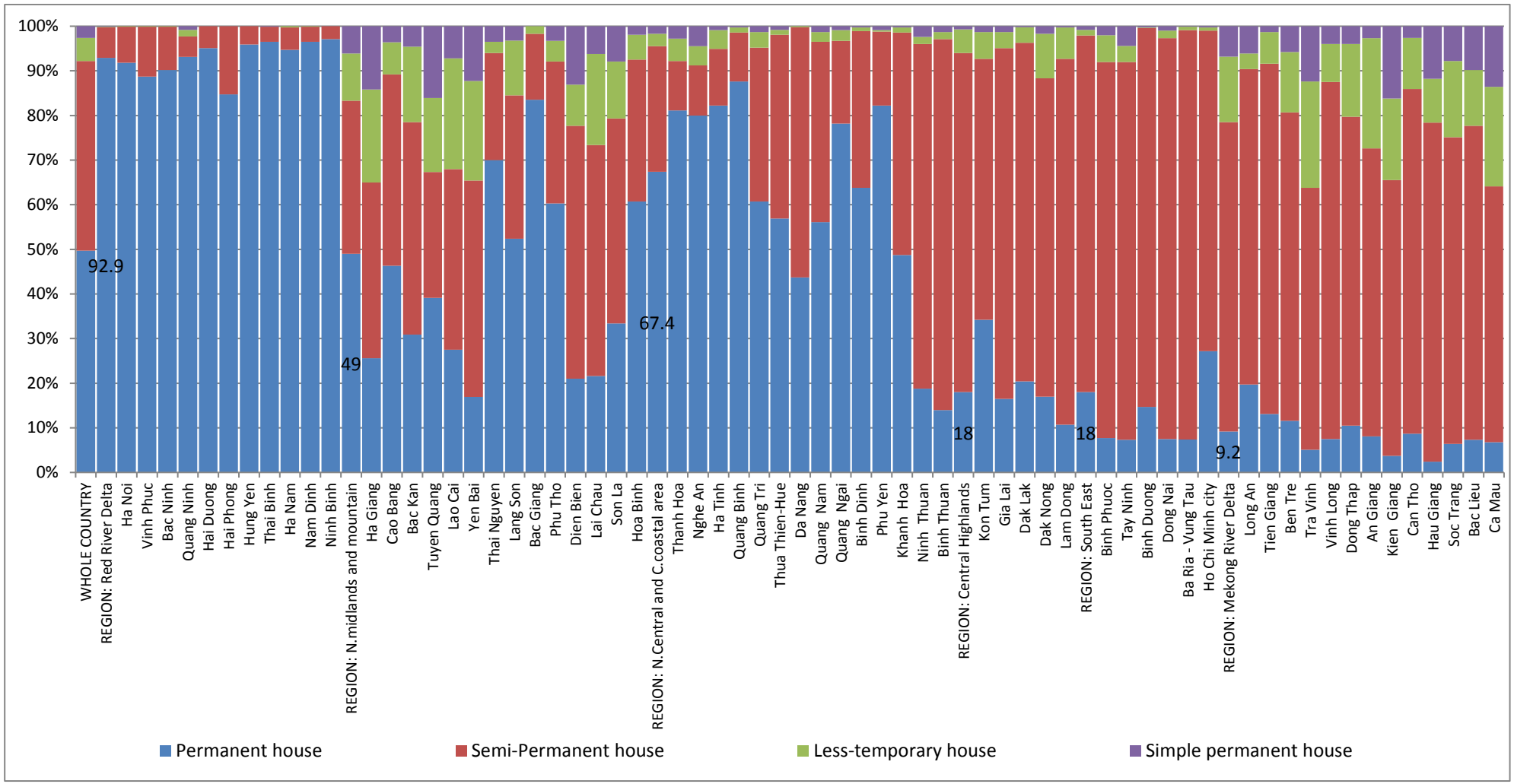


Figure 13: Housing types for Vietnam by city/province and region. Data sourced from GSOV. Data for percentage of permanent housing is shown for each region for comparison purposes.

Figure 13 would suggest that the greatest opportunity for construction materials supply would be in the Mekong River Delta region where the lowest proportion of households have a 'permanent house', followed by the South East region and the Central Highlands region. However, the Mekong River Delta region has the lowest overall percentage of population growth of only 14 per cent compared to the South East (77 per cent) or Central Highlands (68 per cent) which have the highest.

6.1.4 Estimating housing floors construction at city level

The data for quantity of housing floors constructed is only available from the GSOV at regional level, but combining these data with population growth figures enables an estimate to be made at city level for Hanoi. Starting with the data for the area of housing floors constructed in the entire Red River Delta region and using the average population per year to calculate a population growth in that year, it can be calculated that the area of housing constructed per person ranges from 90 m^2 to 120 m^2 per year. Over the 2010 to 2015 time period this averages at 103 m^2 per person. Next a population growth for Hanoi can be calculated from the average population per year and applying the average square metres of housing floors for the Red River Delta region to this reveals that between 9.3 and 16.7 million m^2 of housing floors needs to be constructed in each year in order to provide for the increased population (the calculations are set out in Table 4).

Table 4: Calculations for estimating area of housing floor construction required in Hanoi by the population growth in 2010 to 2015.

Red River Delta	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Area of housing floors constructed (square metres)	17 391 000	23 993 000	22 619 000	18 841 000	22 345 000	21 618 000
Average population (persons)	19 618 100	19 851 900	20 066 100	20 274 900	20 481 900	20 705 200
Population growth (persons)	144 400	233 800	214 200	208 800	207 000	223 300
Area of housing floors constructed per person in population growth (square metres)	120	103	106	90	108	97
Average area of housing floors constructed for each person in population growth (square metres)						103
Hanoi	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Average population (persons)	6 472 000	6 633 600	6 761 300	6 865 200	6 977 000	7 095 900
Population growth (persons)	90 200	161 600	127 700	103 900	111 800	118 900
Estimate of area of housing floor construction required for population growth (square metres)	9 322 179	16 701 376	13 197 808	10 738 075	11 554 541	12 288 327

There is no information available to confirm whether or not this was actually built. The average area of housing floors constructed per capita could also be applied to future projections of population growth to indicate future requirements for housing floor construction.

If data were available describing the quantities of materials needed for a 'typical' house in Hanoi then these could also be applied to the figures in Table 4 to estimate the quantities of materials needed to house Hanoi's growing population. However, these figures would need to include not just the materials needed to build the house but also for the utilities that service the 'typical' house and also allow for other types of construction including workplaces, transportation links, etc. There are published studies that do quote typical material use for urban development but none specific

to Vietnam, figures are given for Taipei, Malaysia and China in Huang et al. (2013), Klufallah et al. (2014) and Fernandez (2007).

7 Hanoi materials supply and demand analysis

Due to the lack of data, a full material flow analysis would not be possible and therefore a different approach was taken, i.e. using the available figures as proxies to examine supply and demand.

An example of using proxy data is as follows: use production and trade data to calculate national apparent consumption, then divide this by the population to obtain a figure for consumption per capita. The result can be converted to Hanoi specific figures by multiplying the consumption per capita by the population of Hanoi. Then using these figures, the material demands of Hanoi can be calculated and predictions can be made about potential future demand scenarios.

7.1 PRODUCTION, TRADE AND APPARENT CONSUMPTION

Apparent consumption is estimated based on the formula:

Apparent consumption = production + imports – exports +/– stock change

As stock changes tend to be temporary when considering construction minerals, no account of stocks is taken into consideration in this study. It is imperative when using this method that all the various trade statistics codes used to describe a particular commodity are taken into account.

Five separate commodities have been included in this analysis that are considered to be the most important in terms of construction of housing and infrastructure in a modern city. These are:

- Sand and gravel
- Crushed rock
- Cement
- Bricks
- Steel

Official consumption statistics are occasionally quoted in news articles regarding the construction sector but official documents are not publically available. However the few available statistics seem to broadly agree with the calculations made by this study. For example an article from the Vietnamese cement association (Vietnam Cement Association, 2017) states the first quarter cement consumption to be 12.9 million tonnes for 2017 (approximately 50 million tonnes per year) this study estimated cement consumption at 62 million tonnes for 2016 and 54 million tonnes for 2015.

7.1.1 Production data

As discussed earlier there is no publically available mineral production data at city level for Hanoi. It is possible that a regional or central government department, (i.e. the Ministry of Construction, Ministry of Building Materials or Hanoi City Peoples Committee) may collect this information and occasional quotes in related news articles certainly suggests a greater granularity of data than just national level exists however it has not been obtainable for this study.

All mineral production data has been sourced from the General Statistics Office of Vietnam (GSOV), which has a comprehensive on-line database for national mineral production. However, data prior to 2007 is not comprehensive so this has been used as the earliest year of reference for this study. Data for aggregates is given in thousand cubic metres, therefore some assumptions have been made to convert these figures into kg and the following densities were applied: crushed rock

2500 kg/m^3 and sand and pebbles 1640 kg/m^3. The densities applied were based on those BGS has used for previous work and were derived via consultation with the UK aggregates industry.

The production figures from the GSOV were validated to some extent by the few pieces of information available in the published literature. For example, Bernardi et al. (2014) state that in 2011 the sand mining rate in the Red River Delta was 6.6 million m^3 upstream of Hanoi and 2.3 million m^3 downstream so approximately 9 million m^3 of sand production from the Red River Delta (which is assumed to be the main producing area feeding into Hanoi). Using population figures to calculate per capita production the GSO reported figures indicate that Hanoi produces around 4.3 million m^3 per year.

One major issue with production data for aggregates for Vietnam is the unknown quantity of illegally mined material. This could form a significant part of total annual production. However, it is not known how much is illegally mined or if attempts are made to accommodate this in the official statistics. One possible indicator for the levels of illegal production is from a quote from the Ministry of Construction Department of Construction Materials with states that the legal sites for sand extraction can only meet 60-65 per cent of demand for major Vietnamese cities, this implies the remainder is from illegal sources (Viet Nam News, 2017b; Vietnam News Agency, 2017).

For cement, the country has 82 production lines of rotary kiln with a total annual capacity of 97.64 million tonnes (Cement News, 2018), this compares with an annual reported production of 77.3 million tonnes. It is also reported by industry sources that Vietnam consumed 49 million tonnes of cement in 2012 (Global Cement, 2012). This compares with the apparent consumption of 54 million tonnes as calculated as part of this research.

Regarding production data for steel, there are several data series available. Official data from the GSOV is presented separately for steel bars and steel. The USGS presents the GSOV data but labels steel bars as ‘crude steel’ and steel as ‘rolled steel’ (Fong-Sam, 2014). The official BGS data series comes from the World Steel Association and is different (Brown et al., 2017). This could be because the BGS figures represent true crude steel production whereas the GSOV figures (as also presented by USGS) represent both finished products as well as crude steel. However, this is not clear and needs to be confirmed. For this MFA study, only the data for steel from GSOV was utilised to ensure consistency with the methodology used for the other commodities.

The effects that government legislation and market forces has had on production are clearly visible in past trends (Table 5). The ban by Indonesia on sand exports in 2007, followed by Cambodia in early 2009 caused an increase in production from Vietnam (much of which was subsequently exported) as producers moved to fill the hole in the market. This rise in production (and also exports) ceased in 2010 due to the ban by Vietnam in mid-2009 on the export of non-marine sand. It remains to be seen if the outright ban of all sand exports from Vietnam made in September 2017 will further reduce production figures. These effects likely mask an increase in demand from Hanoi in recent years.

It can be noted that across all commodities, with the exception of steel, in the period from 2011 to 2013 production decreased (Table 5). This was due to a slowing of the growth rate of the Vietnamese economy during this period as a result of high interest rates, high ratios of bad debt, a slowdown in the real estate market and difficulties in gaining capital (Van Vu, 2016). However a subsequent improvement in the Vietnamese economy has also seen production in all commodities increase significantly.

Table 5: Vietnam production of construction materials, million tonnes (source: GSOV).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cement production	37	40	49	56	58	56	58	61	68	77
Steel production	5	5	7	8	8	8	9	11	13	15
Bricks production	45	55	57	61	60	52	52	52	55	57
Sand and gravel production	110	105	115	103	95	78	82	85	87	90
Crushed rock production	232	305	342	367	389	342	335	368	395	413

7.1.2 Trade data

Similar to the mineral production data, the only publically available trade data is at the national level. Although regional, or city level, data may exist, BGS did not have access to them for this study. Therefore for the five commodities being assessed, all trade data were obtained at national level from the UN Comtrade website, a website run by the United Nations which collates international trade data (Table 6). Unfortunately Vietnam only reports its trade in monetary terms whereas this study required a unit of mass. Therefore instead of using data reported by Vietnam the imports and exports reported by other countries to and from Vietnam were used instead as these were given in kg.

Data from UN Comtrade is categorised according to trade codes. The following trade codes were used.

- aggregates 2517 and 2505;
- cement 252310, 252321, 252329, 252330 and 252390;
- bricks 6904, 681011 and 681019 (refractory products were not considered here); and
- steel 720712, 720719, 720720, 721810, 721891, 721899, and 722490.

The effects of various legislation prohibiting sand exports described in the production section can also be clearly seen in the trade statistics for sand (Table 6).

7.1.3 Apparent Consumption data

Apparent consumption was calculated using the formula stated above. First apparent consumption for Vietnam was calculated using national figures. This was then converted to consumption per capita by dividing the total apparent consumption by the population. Using this, the apparent consumption for Hanoi can be calculated by multiplying the population of Hanoi by the apparent consumption per capita Figure 14. This methodology is reliant on all material produced being consumed, however if there is significant market oversupply it is possible for production to become decoupled from consumption. For instance if new production capacity is brought online that is difficult to quickly shut off. Cement is an example of this, where production capacity in

Vietnam is predicted to outstrip demand by as much as 26 million tonnes by 2020 due to construction of new plants (Global Cement, 2018).

Table 6: Vietnam trade of construction materials, thousand tonnes (source: UN Comtrade).

		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cement	Imports	3 966	3 712	3 730	2 405	1 009	488	129	175	143	778
	Exports	10	37	29	1 592	5 353	10 958	15 377	8 987	13 958	15 952
Steel	Imports	901	868	1 427	1 369	514	356	305	291	512	657
	Exports	0.69	100	7	1	30	20	31	47	20	3
Bricks	Imports	3	8	5	4	5	2	9	8	10	18
	Exports	19	41	21	21	30	72	94	118	100	82
Sand	Imports	4	59	5	2	5	12	4	13	12	20
	Exports	2 647	7 150	28 170	5 332	1 356	1 205	6 775	11 777	13 138	8 479
Crushed rock	Imports	943	4 770	5 661	8	8	16	4	6	4	19
	Exports	603	516	172	65	72	113	123	543	394	378

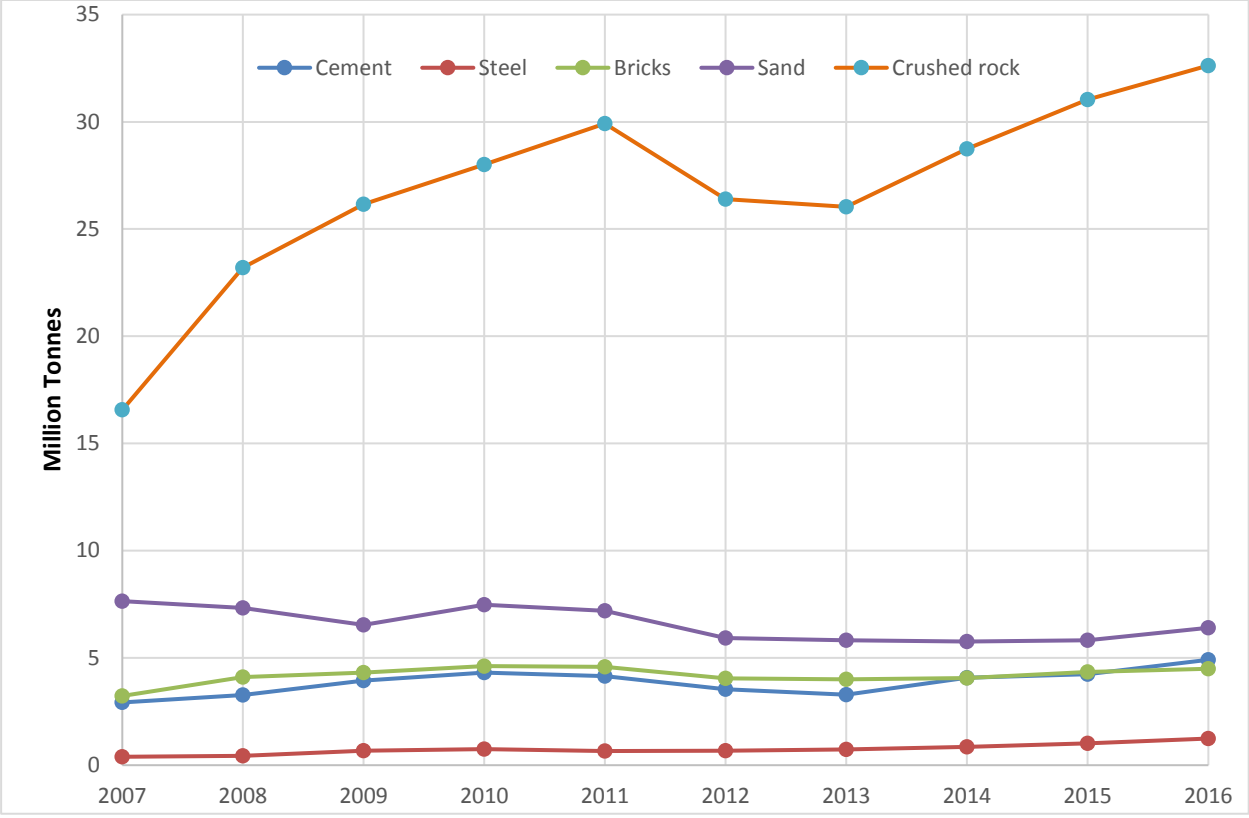


Figure 14: Apparent consumption for Hanoi.

7.2 PROJECTIONS OF FUTURE DEMAND

The Ministry of Construction have published some projection figures for future demand for sand. One report states national demand for sand will increase from around 92 million m^3 (this is around 150 million kg) in 2015 to 130 million m^3 (or 213 million kg) by 2020 (Viet Nam News, 2017a). These figures do not seem to match the published production figures of around 90 million kg for 2016 and this could possibly indicate the scale of illegal extraction. A separate report from the Ministry of Construction states that between 2016 and 2020 domestic demand for construction sand is estimated to be 2.1–2.3 billion m^3 between 2016 and 2020 (Cafef, 2017). This is an order of magnitude higher than the reported production figures and seems at odds with reported reserves of 2 billion m^3, highlighting some of the uncertainty that surrounds these data.

There are figures available for projections of population growth in Hanoi which have been sourced from the Hanoi master plan to 2020. These state that the population is forecast to grow to 7.44 million by 2020, 9.2 million by 2030 and 10.8 million by 2050 (NhanDan, 2011). These figures allow the annual population growth for Hanoi to be predicted. The apparent consumption of materials for Hanoi can be predicted using this population trend and the trend of per capita consumption for the last 10 years. Different scenarios can also be estimated using the highest and lowest growth rates for per capita consumption seen over the last 10 years. This analysis has been undertaken for all commodities in this study as shown by Figure 15 to Figure 19. The following equations explain in more detail how future demand was projected.

- *Step 1: Calculation of the compound annual growth rate of consumption per capita between 2007 and 2016*

$$CAGRC_{y(a\ to\ x)} = \left[\left(\left(\frac{C_{y(x)}}{C_{y(a)}}\right)^{\left(\frac{1}{t}\right)}\right) - 1\right] \times 100$$

CAGR = compound annual growth rate (%)

$C_{y(x)}$ = consumption per capita in 2016 (kg)

$C_{y(a)}$ = consumption per capita in 2007 (kg)

t = time period between year y_x and y_a

- *Step 2: Forecast consumption per capita to 2030*

$$C_{y(z)} = C_{y(z-1)} + CAGRC_{y(a\ to\ x)} \times C_{y(z-1)}$$

C_{yz}=consumption per capita in year z, after 2016 (kg)

- *Step 3: Forecast consumption for Hanoi to 2030*

$$HC_{y(z)} = C_{y(z)} \times P_{y(z)}$$

$HC_{y(z)} = Hanoi\ forecasted\ consumption\ in\ year\ z, after\ 2016$ (Kg)

$P_{y(z)} = Hanoi\ forecasted\ population\ , after\ 2016\ (thousand\ of\ persons)$

The vertical lines appearing in the graph from year 2017 to 2030 have been constructed using an average standard deviation figure measured from the Hanoi consumption figures in the past 10 years and are added to illustrate the potential discrepancies in the main trend line that may be observed in the future.

The results suggest growing demand for all materials as summarised in Table 7:

Table 7: Increase in forecasted demand for key construction materials in Hanoi by 2030.

Key construction materials in Hanoi	**Forecasted demand in 2030 compared to 2016 data**
Cement	Increase 2-fold
Bricks	Increase 1.5- fold
Sand & gravel	Increase 2-fold
Crushed rock	Increase 2.5-fold
Steel	Increase 5-fold

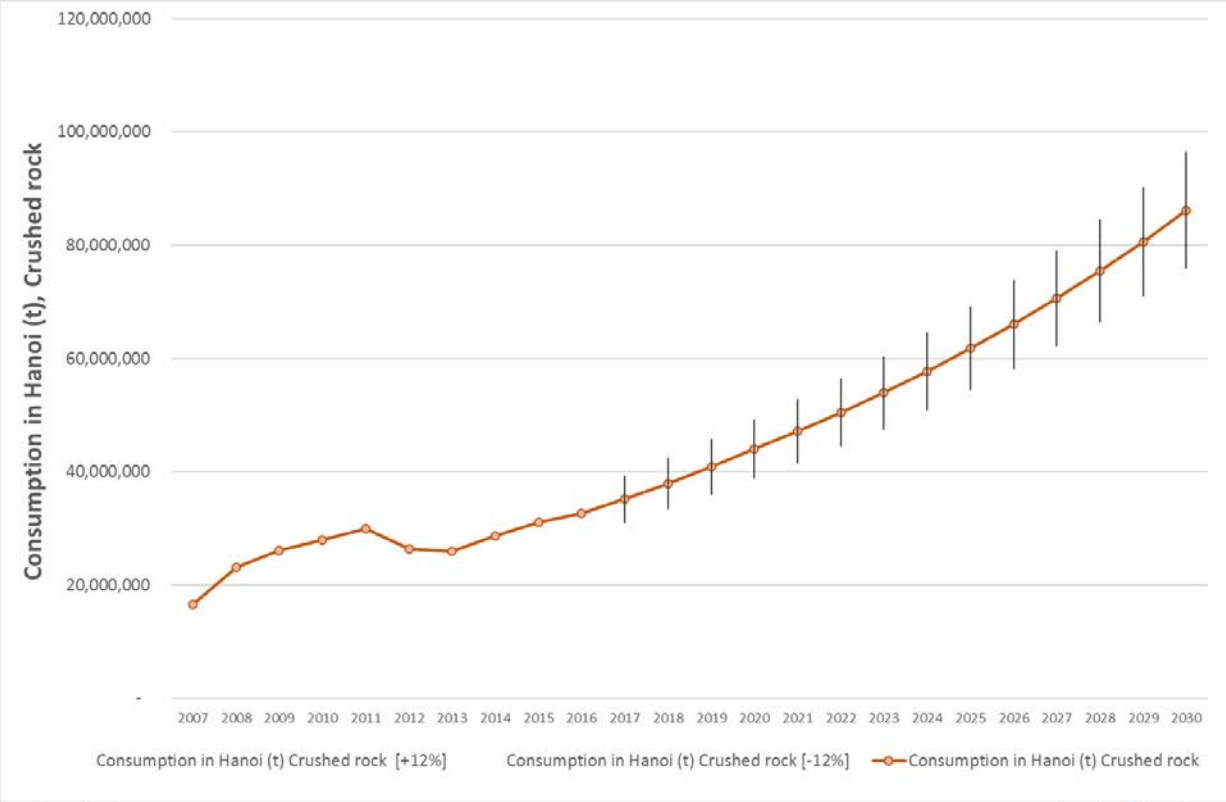


Figure 15: Hanoi consumption of crushed rock (2007 to 2030).

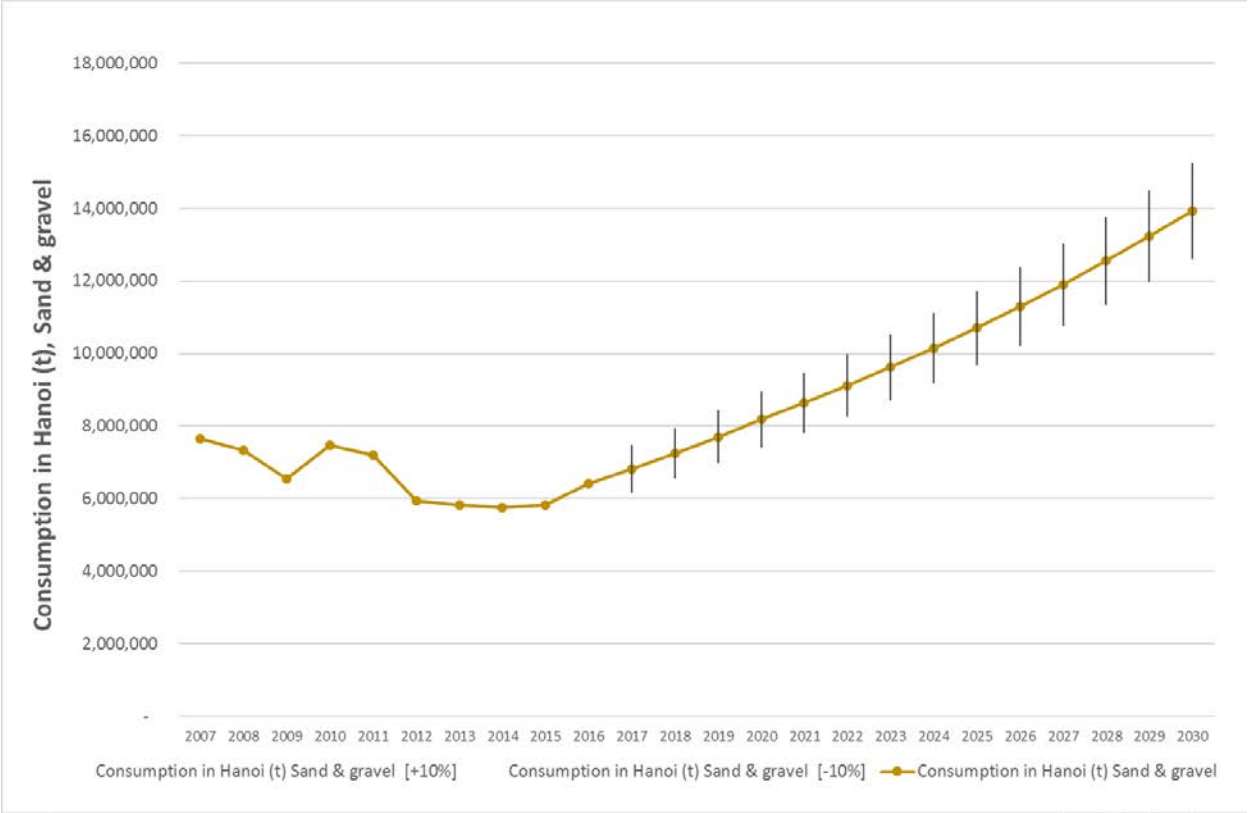


Figure 16: Hanoi consumption of sand and gravel (2007 to 2030). Note CAGR from reported production is not considered realistic as it is likely more sand is produced from informal and illegal mining, as a result the CAGR from cement has been used instead.

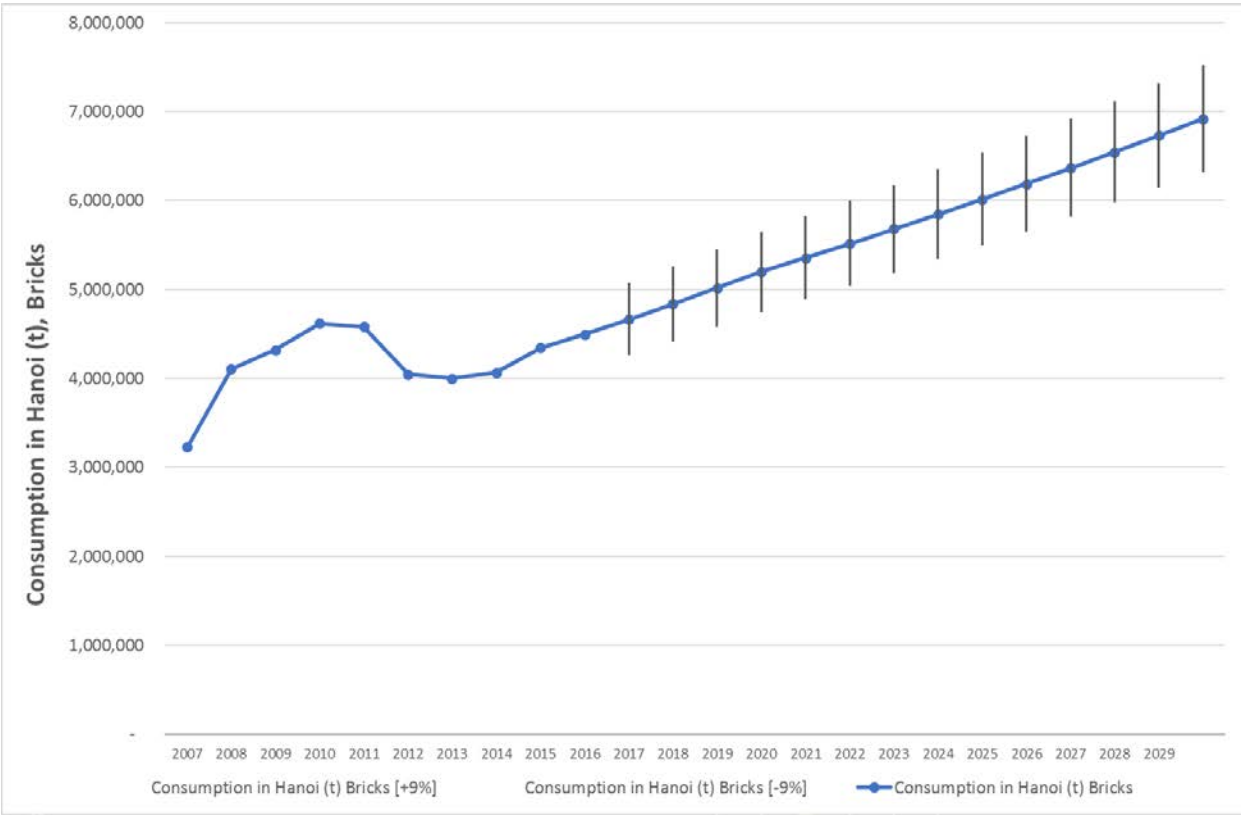


Figure 17: Hanoi consumption of bricks.

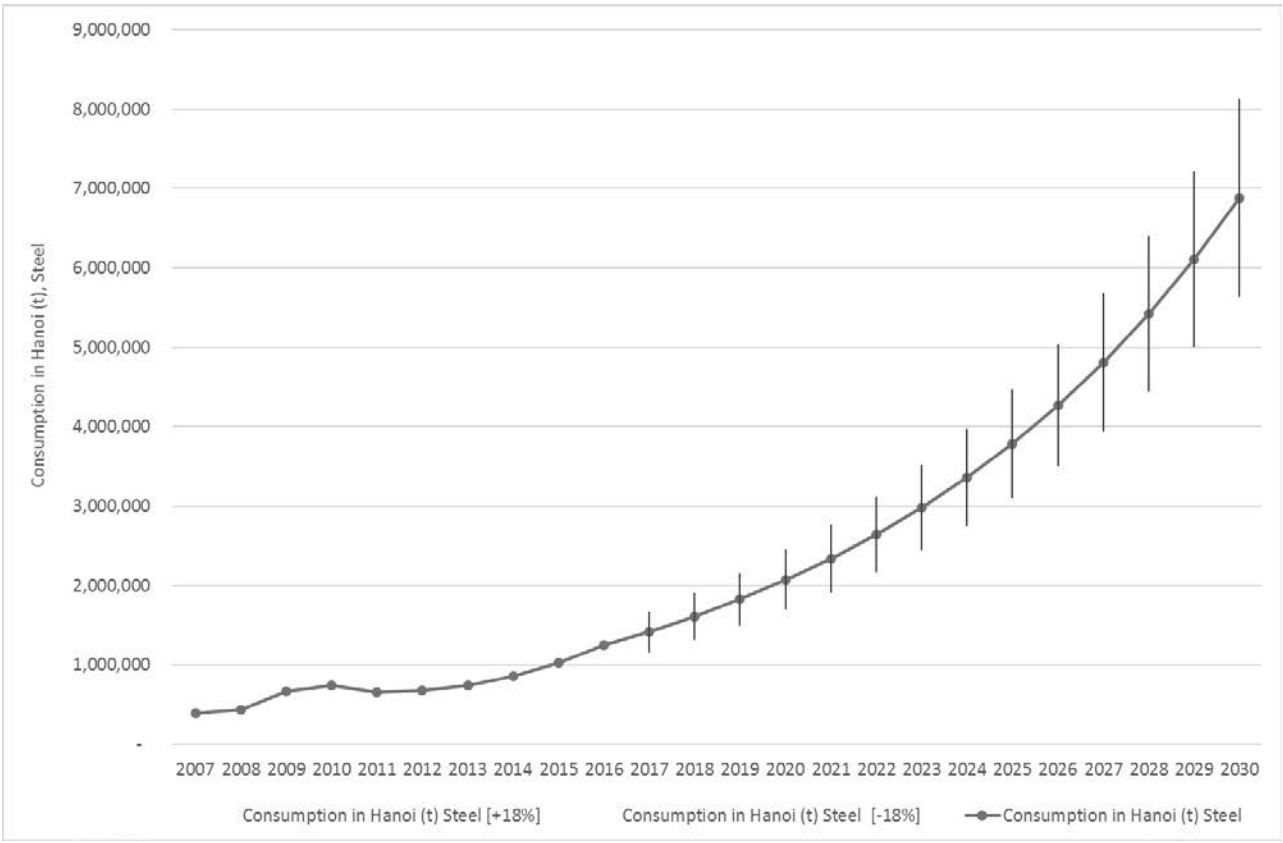


Figure 18: Hanoi consumption of steel.

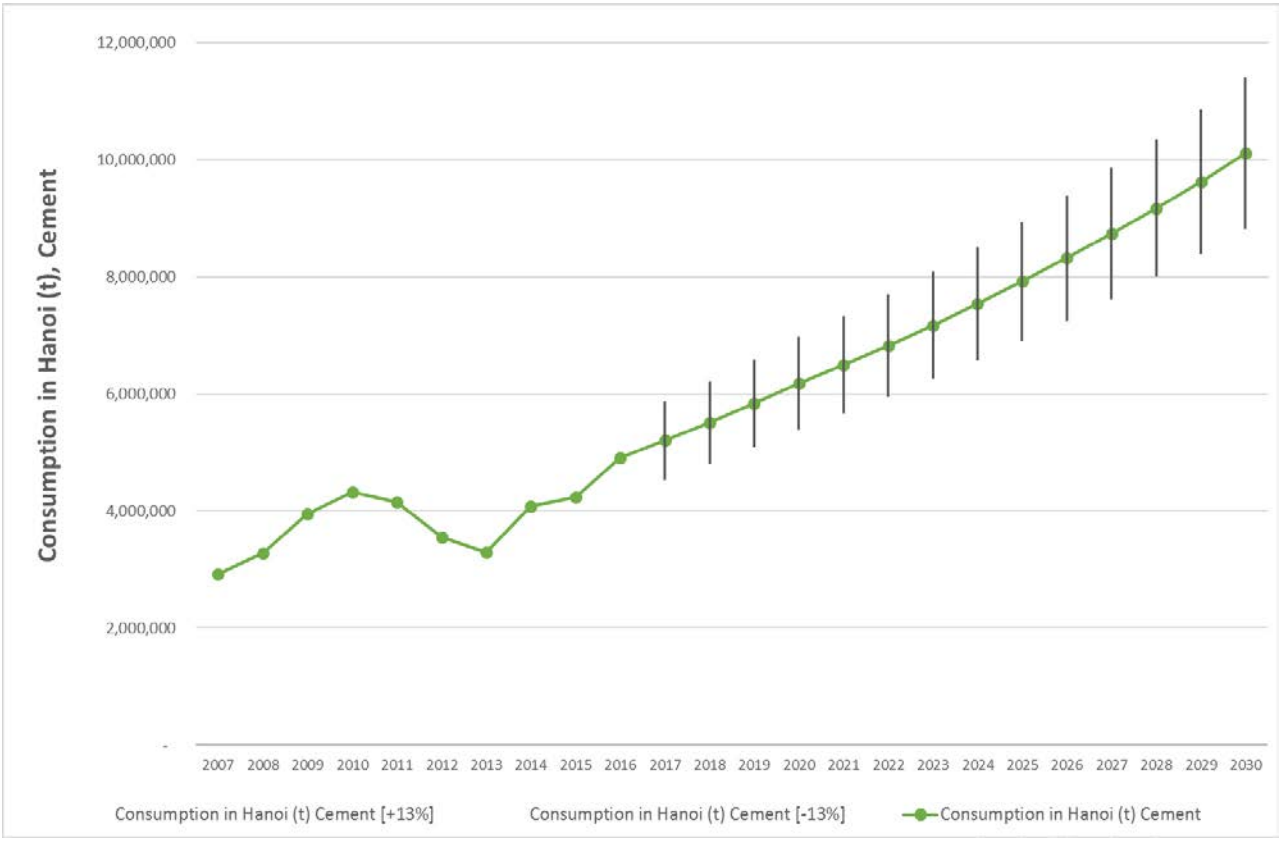


Figure 19: Hanoi consumption of cement.

8 Conclusions

This research attempted to model the increase in demand for construction materials in Hanoi resulting from the predicted urban development and to understand the implications of this material intensive urban growth. The study comprised a desk-based assessment using publicly available data from 'national' and international sources. The project delivered the following:

- A methodological framework for assessing construction material demand in Hanoi based on the MFA principles.
- A detailed assessment of data availability and gaps.
- An overview of the urban growth plans of Hanoi.
- A forecast of the construction material demand to 2030, based on a top-down approach.

Although the level of available data is insufficient to conduct a detailed material flow analysis, conclusions regarding material use in Hanoi can be drawn from the top-down calculation undertaken.

- Data limitations and a lack of understanding of how materials are produced, consumed and reach their end-of-life in the city of Hanoi limit our ability to develop a detailed material flow analysis for the city of Hanoi and to quantify associated environmental and social impacts.
- The top-down quantification followed in this work made use of publicly available data. However, uncertainties regarding the quality of these data exist, which also influence the projections made. Additional effort to identify the associated uncertainties through direct dialogue with stakeholders in Hanoi would help to obtain a better understanding of the data issues and facilitate enhanced modelling of the material demand projections accordingly.
- It would appear that the Ministry of Construction collects more information on primary raw materials; however, these are not publically available. Access to reports published by the Ministry of Construction would be greatly beneficial to this work.
- News articles and press releases by Vietnamese government agencies indicate that supply of materials for construction is currently a real issue. Supply bottlenecks are causing project delays, price rises and illegal mining, and in the future may result in significant supply disruption and negative environmental implications.
- Statistics on housing and population show Hanoi is likely to continue to rapidly grow in the short to medium term.
- Despite a dip around 2009-2012 (due to a slowdown in the Vietnamese economy and construction market) consumption of materials shows a clear increase, often in the region of between 10 and 20 per cent year-on-year.
- Sand consumption shows a more complex trend. This is most likely due to the effects of national legislation, international trade and issues around illegal mining. The official data on sand and gravel production are believed to include high uncertainties due to the hidden flow of illegal mining taking place as reported by literature. The missing information and data also become apparent when comparing cement production and consumption to the sand and gravel figures, which do not align as expected.
- Projections for future consumption of five key construction materials predict between a twofold increase in requirements for cement and sand and gravel to fivefold increase for steel by 2030 based on 2016 consumption levels. It is unclear however whether relevant decision makers in Hanoi and Vietnam overall are prepared for this forecasted increase and have plans to expand production and increase processing capacity in place to ensure that future demand is met. Ensuring such requirement for materials is met will require careful management of existing resources and planning for sourcing new resources as well as new processing and production facilities (e.g. increase capacity in cement production).

- Demand for construction materials extracted from Vietnam but supplied to neighbouring countries present an increasing trend. For example, net exports of cement from Vietnam have increased by 126 per cent in the past 10 years. Although such trade provides an important driver for economic growth, at times of rapid domestic urbanisation and looking into the near future, it can pose a potential risk to domestic supply and link to increased environmental implications (e.g. higher greenhouse emissions).
- Future research should focus on better management of resources across the value chain with the aim to identify bottlenecks on time and avoid the consequences of supply disruption.
- Increased uptake of green building certification schemes, such as the US Green Building Council's LEED (Leadership in Energy and Environmental Design) and the Vietnam's LOTUS (VGBC) will require detailed information about the origin and fate of construction materials and their associated environmental impacts. Studies on material flows and stocks supported by energy and water consumption layers can provide essential background information and conform to certification scheme requirements.
- The development of a system to track material flows and stocks at city level provides a powerful accounting tool that can find use in different circumstances, for example to assess market dynamics with respect to material requirements, to monitor progress towards set targets (e.g. on sustainability, clean production, urban growth, recycling etc.) and to inform decision making.

9 Next steps

The next steps in this project include:

1. A bottom up quantification of future supply and demand (Figure 3). Statistical data related to buildings and construction were collected during this first stage of the project, but have not been used to their full potential. This is due to additional data requirements related to building types, building density, building stocks and material compositions that have not been investigated and where data gaps exist. Additional review of available literature and, if possible, discussions with stakeholders in Vietnam is required. Another area that should be explored is the use of remote sensing data that may prove useful in quantifying some of these parameters to enable the research to progress quicker.

2. The ultimate goal of this project is the development of a full material flow analysis model for Hanoi. This type of analysis would have many benefits. For example:

- Mapping material flows and stocks at city level provides essential background information on raw material availability, use and recycling. It can identify risks and supply disruption issues that can be mitigated by tailored interventions. The outcomes of material flow analysis can assist effective decision making and the planning of urban development projects.
- Several additional layers can be built on material flow maps, for instance, to identify the interrelationships of energy consumption and raw material use, or raw material use and land use, and many more.
- Material flow maps can identify opportunities for improving the recovery and recycling of end-of-life products and their use as feedstock back into construction.
- Material flow maps clearly outline the impact that trade has on raw material within the specified system boundaries (e.g. single country or city).
- Hidden flows, such as illegal mining can be identified during the analysis.

The first step in material flow analysis includes the development of a system that describes the stages and processes that materials go through from extraction to end of life. Such a system does not exist for the city of Hanoi and in order to develop it, engagement with Vietnamese stakeholders will be required. The materials flow analysis can be complex due to the great range of sources of materials entering the system. The processing and trade of these materials into different forms coupled with often a lack of data, especially on a regional/city level, requires careful consideration. In addition, the analysis will require significantly more data some of which may be available in the public domain and others that require input from stakeholders in Hanoi. Therefore, for this research to effectively progress it is critical that discussions are held with the relevant government ministries which deal with construction materials in both Hanoi and Vietnam. This will provide essential underlying understanding about data availability and accessibility from Vietnamese stakeholders to third parties. It is also important to understand whether complementary MFA-type projects are already being undertaken in Vietnam. It is clear from press releases and news articles that issues surrounding supply of construction materials are being considered by local and national government and BGS will need to engage with relevant authorities to ensure any work undertaken aligns with the needs of stakeholders in Vietnam.

Other future research in this area may involve analysing trends in similar developing countries, or countries that have undergone rapid urbanisation (e.g. China) to see if parallels can be drawn with Vietnam. This may help with predicting future trends and also for filling data gaps, for example on the material composition of buildings. There is also merit in investigating in more detail statistical methods for predicting future trends to ensure demand forecasts can be generated in a robust manner.

Appendix 1 National mineral production statistics

Mineral production in Vietnam

Commodity	UNITS	2012	2013	2014	2015
Alumina	tonnes (Al2O3 content)	0	214000	485000	494000*
Alumina	tonnes (metric)	0	214000	485000	494000
Antimony	tonnes (metal content)	480	990	1098	996
Barytes (Barytes)	tonnes (metric)	90000	90000	140000	140000
Bauxite, Alumina & Aluminium (Bauxite)	tonnes (metric)	100000*	482000	1090000	1112000*
Bentonite & Fuller's Earth (Bentonite)	tonnes (metric)	20000*	20000*	20000*	20000*
Bismuth	tonnes (metal content)	0	0	646	1510
Chromium (Ores & concentrates)	tonnes (metric)	1800*	24800*	0*	0*
Coal (Anthracite)	tonnes (metric)	42083000	41064000	41086000	41518200
Cobalt	tonnes (metal content)	0	0	223	277
Cobalt	tonnes (metric)	0	0	223	277
Copper (Mined)	tonnes (metal content)	12716	12958	20296	22592
Copper (refined)	tonnes (metric)	8000*	9700*	9700*	11000*
Copper (Smelter)	tonnes (metric)	8000*	9700*	9700*	11000*
Diatomite	tonnes (metric)	10000*	10000*	10000*	10000*
Feldspar	tonnes (metric)	200000*	200000*	200000*	200000*
Fluorspar	tonnes (metric)	4000*	4000*	90940	193164
Gold	kilograms	1508	1681	164	110*
Gypsum	tonnes (metric)	5000*	5000*	5000*	5000*
Iron Ore	tonnes (metric)	1506200	2495300	2719000	2237800
Kaolin	tonnes (metric)	650000*	650000*	650000*	650000*
Kaolin	tonnes (metric)	650000	650000	650000	650000
Lead (mined)	tonnes (metal content)	200*	0*	1400*	700*
Manganese Ore	tonnes (metric)	15800*	9700*	800*	0*

Natural Gas	million cubic metres	9355	9751	10210	10660
Nickel (Mined)	tonnes (metal content)	0	1166	6854	8607
Petroleum (Crude) (a)	tonnes (metric)	17305300	17390000	17392000	18746000
Phosphate Rock	tonnes (metric)	2363800	2656100	2470900	2758100
Pig Iron	tonnes (metric)	650000*	650000*	1393000*	1393000*
Rare earth oxides	tonnes (metric)	0*	100*	100*	100*
Salt	tonnes (metric)	776400	718100	905600	991000
Steel Ingots and Castings (Crude steel)	tonnes (metric)	5298000	5474000	5847000	6050000
Talc (Pyrophyllite)	tonnes (metric)	16000*	16000*	16000*	16000*
Tin (mine)	tonnes (metal content)	5400*	5400*	5400*	5400*
Tin (Smelter)	tonnes (metric)	4800*	5500*	5500*	5500*
Titanium (Ilmenite)	tonnes (metric)	978300	1025800	558000	282200
Tungsten	tonnes (metal content)	0	0	4134	5123
Zinc	tonnes (metal content)	25000*	20000*	17000*	17000*
Zinc (Slab)	tonnes (metric)	18000*	12000*	12000*	10000*
Zirconium minerals	tonnes (metric)	21000*	7000*	7000*	1000*

Source: BGS world mineral production database

(a): including natural gas liquids

Appendix 2 Organisations that may have data for materials flow analysis

- Ministry of Construction http://www.xaydung.gov.vn/web/guest/english
- General Statistics Office of Vietnam http://www.gso.gov.vn
- Department of Construction Hanoi http://www.soxaydung.hanoi.gov.vn/vi-vn
- General Department of Geology and Minerals in Vietnam (DGMV) http://dgmv.gov.vn
- Vietnam Association for Building Materials http://hoivlxdvn.org.vn/trangchu.html
- Vietnam Cement Association http://www.vnca.org.vn/vn/

Appendix 3 Data sets with useful information for Vietnam/Hanoi

Dataset name	Data coverage	Data type	Link	Commodity	Notes
BGS statistics database	Vietnam	statistics	BGS world mineral production database	metals/industrial minerals	This has total production for Vietnam for a range of metals and industrial minerals (no construction materials), the main source is the Vietnamese statistics office.
UN Comtrade	Vietnam	statistics	https://comtrade.un.org/data/	all	This is a database of world trade. You can search for exports or imports of a variety of commodities (HS code). There are some codes which cover aggregates but they include several different commodities. Data can be viewed annually or monthly and via world trade or trade with individual countries.
WBMS	Vietnam	statistics	Held by BGS	non-ferrous metals	Data BGS receives from the World Bureau of metal statistics this includes data on trade, consumption and production.
USGS country profile	Vietnam	report/statistics	https://minerals.usgs.gov/minerals/pubs/country/2013/myb3-2013-vn.pdf	all	A report detailing the minerals industry of Vietnam (from 2013) with production of all commodities.
sand prices see sharp increase	Hanoi	news	http://bizhub.vn/news/sand-prices-see-sharp-increase_285412.html	construction materials	A news article detailing the issues over restricted sand supply in Hanoi from April 2017, it contains price and demand information nationally for Vietnam.
Price of Vietnam sand rises due to limited supply	Hanoi/Vietnam	news	http://english.vietnamnet.vn/fms/business/178911/price-of-vietnam-sand-rises-due-to-limited-supply.html	construction materials	News article detailing supply restrictions, price details, demand and issues surrounding sand supply in Vietnam. These articles mention a report by the department of construction minerals (which does not appear to be available). See also http://english.vietnamnet.vn/fms/environment/177819/sands-of-time--vn-faces-severe-shortage.html
Sand becoming depleted because of illegal exploitation	Vietnam	news	https://www.myhanoi.info/2017/05/sand-becoming-depleted-because-of-illegal-exploitation-export/	construction materials	News article detailing supply issues with resources estimates demand estimates and projections and information on illegal operations. See also http://english.vov.vn/economy/vietnam-faces-severe-sand-shortage-349192.vov

Vietnam ministry of construction	Vietnam	website	The /trang-vat-lieu-xay-dung	construction materials	The website of the Ministry of Construction. This does not appear to have any relevant information, although it is a complex website all in Vietnamese. There are numerous government policy articles related to changes of planning conditions on individual operations but nothing more holistic.
Vietnam statistics office	Vietnam	website/statistics	http://www.gso.gov.vn/default_en.aspx?tabid=779	all	The data portal for the Vietnamese statics office. This gives production data for most commodities but only up to 2015.
Vietnam statistics office	Vietnam	report/statistics	http://www.gso.gov.vn/default_en.aspx?tabid=515&idmid=5&ItemID=16052		Similar to above but with indexed housing and construction data as well.
sand shortages delays transport projects	Vietnam	news	http://english.vietnamnet.vn/fms/society/180027/sand-shortage-delays-transport-projects.html		News report regarding recent shortages of sand and how they are adversely affecting construction projects.
construction materials prices in Hanoi	Vietnam	website	http://www.soxaydung.hanoi.gov.vn/vi-vn/tin/cong-bo-gia-vat-lieu-xay-dung-quy-iii-2016/449130-704512-192517		Website of the department of construction Hanoi this has price information - all in Vietnamese.
department of geology and minerals in Vietnam	Vietnam	website	http://dgmv.gov.vns%C3%B4ng&Itemid=357&lang=vi	all	Website of the Ministry of Mining and Minerals Not much relevant data – and difficult to navigate as all in Vietnamese. See also this link which has some percentages for what could be illegally mined material.
The supply of sand is depleted, the demand for replacement materials is increasing	Vietnam	news	http://cafef.vn/nguon-cung-cat-can-kiet-nhu-cau-vat-lieu-thay-the-ngay-cang-cao-20170517152304692.chn	construction materials	News article - an interview with the director of the association for building materials on the state of the Vietnamese sand industry.
Vietnam association for building materials	Vietnam	website	http://hoivlxdvn.org.vn/trangchu.html	construction materials	The website for the Vietnamese association for building materials - there is no relevant data but it may be a useful contact.
article on illegal sand extraction	Vietnam	news	http://vnexpress.net/tin-tuc/thoi-su/pho-thu-tuong-mo-dot-cao-diem-tan-cong-cat-tac-3551882.html		Some useful statistics in this article on the number of operations dredging rivers for sand and proposals in the pipeline etc.

Statistics on construction materials production in the first 6 months of 2016	Vietnam	news	https://translate.google.co.uk/translate?hl=en&sl=vi&u=http://vatlieuxaydung.org.vn/tin-tuc/thong-ke-ve-san-xuat-vat-lieu-xay-dung-trong-6-thang-nam-2016-7392.htm&prev=search	construction materials	A news article on some statistics on construction material production from the department of construction. The original does not seem to be on the department website however.
cement market	Vietnam	news	https://translate.google.co.uk/translate?hl=en&sl=vi&u=http://ximang.vn/bien-dong-thi-truong/thi-truong-xi-mang/quy-i-san-xuat-va-tieu-thu-xi-mang-tang-nhe-9507.htm&prev=search	construction materials	Statistics for the cement industry in the form of production consumption prices and trade. This suggests that official data may be available although it does not seem to be present on the official websites.
Recycling construction demolition waste in the world and in Vietnam	Vietnam	report	https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjFrfaeiM_VAhUBJ8AKHUuPABQQFggmMAA&url=https%3A%2F%2Fwww.researchgate.net%2Ffile.PostFileLoader.html%3Fid%3D5231714dcf57d78255b4149f%26assetKey%3DAS%253A273616023818246%2540144246551502&usg=AFQjCNHGXe0qlBsvW7Qd2LSWizw5ftUM4A	construction materials	A paper from 2013 talking about use of construction and demolition waste in Vietnam (there is no recycling).
cement produces trade association of Vietnam	Vietnam	website	http://www.vnca.org.vn/vn/	cement	The cement producers trade association of Vietnam, there is no data post 2012, however, other web links suggest the organisation is still active - http://www.globalcement.com/news/itemlist/tag/Vietnam%20Cement%20Association
Vietnam forecast to run out of construction sand by 2020	Vietnam	news	http://tuoitrenews.vn/news/society/20170803/vietnam-forecast-to-run-out-of-construction-sand-by-2020/40865.html	construction materials	An article regarding an announcement from the ministry of construction on the demand for building materials. The article mentions a report from the ministry but this does not seem to be publically available. See also http://vov.vn/kinh-te/thi-truong/bo-xay-dung-noi-gi-ve-gia-cat-xay-dung-tang-650118.vov
Vietnam bans marine sand exports	Vietnam	news	https://tuoitrenews.vn/news/business/20170808/vietnam-to-halt-saline-sand-exports-indefinitely-after-september/40920.html	sand	A news article describing loopholes in the law allowing illegal exports of marine sand that are about to be banned.

Vietnam halts exportation of silica sand used in glassmaking	Vietnam	news	http://english.vov.vn/economy/vietnam-halts-exportation-of-silica-sand-used-in-glassmaking-362720.vov	sand	A news article with figures for Vietnam silica sand exports stating exports are banned as of 2017.
Trends in Glass making raw materials in Asia	Vietnam	news	http://www.indmin.com/events/download.ashx/document/speaker/6613/a0ID000000X0jo0MAB/Presentation	sand	A PowerPoint from Industrial minerals magazine, this contains several slides specific to the Vietnamese silica sand sector.
Record high sand prices and scarcity: Need early material substitutions?	Vietnam	news	http://cafef.vn/gia-cat-tang-cao-ky-luc-va-khan-hiem-can-som-co-vat-lieu-thay-the-20170923182941722.chn	sand	Useful figures: "According to the Ministry of Construction survey, the demand for sand from 2016 to 2020 should be approximately 2.3 billion m3. While the current reserve is more than 2 billion m3. It is forecasted that by 2020, the use of sand will reach about 130 million m3 / year, there will be no sand for construction." also price of sand in December is 600000VND/M3 - risen by 50-200% in last 6 months.
domestic cement consumption increased by 3%	Vietnam	news	http://hoivlxdvn.org.vn/news/nam-2017-tieu-thu-xi-mang-noi-dia-tang-3-41281.html	cement	Article from the Association for Building Materials and contains figures for cement production and consumption in 2017.
Hanoi will build more than 400,000 square meters of social housing in 2018	Hanoi	news	http://hoivlxdvn.org.vn/news/ha-noi-se-xay-them-hon-400000-m2-nha-o-xa-hoi-trong-nam-2018-41376.html	housing demand	Article from the Association for Building Materials stating housing growth and average space per person in housing for Hanoi.
The country produces 7 billion unburnt bricks	Vietnam	news	http://hoivlxdvn.org.vn/news/ca-nuoc-san-xuat-7-ty-vien-gach-khong-nung-41283.html	brick production	Article from the Association for Building Materials with brick production figures.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: https://envirolib.apps.nerc.ac.uk/olibcgi.

AROURI, M, BEN YOUSSEF, A, AND NGUYEN, C. 2017. Does urbanization reduce rural poverty? Evidence from Vietnam. *Economic Modelling*, Vol. 60, 253-270. http://www.sciencedirect.com/science/article/pii/S0264999316304461

BERNARDI, D, BIZZI, S, SCHIPPA, L, SCHMITT, R, AND SONCINI-SESSA, R. 2014. Accounting for river morphology in the management of red river (Vietnam): a numerical modeling approach. *3rd European Congress of the International Association of Hydraulic Engineering*, 1-11.

BROWN, T, IDOINE, N, RAYCRAFT, E, SHAW, R, DEADY, E, HOBBS, S, AND BIDE, T. 2017. *World Mineral Production 2011-15*. (British Geological Survey.) ISBN 0852728670

CAFEF. 2017. Record high sand prices and scarcity: Need early material substitutions? : Cafef. [cited 2/3/2018]. http://cafef.vn/gia-cat-tang-cao-ky-luc-va-khan-hiem-can-som-co-vat-lieu-thay-the-20170923182941722.chn

CEMENT NEWS. 2018. Vietnam produces 7.2Mt of cement in January. Cement News. [cited 31/1/2018]. Cement News. https://www.cemnet.com/News/story/163346/vietnam-produces-7-2mt-of-cement-in-january.html

DUNG, N M. 2011. *River sand mining and management: a case of Cau river in Bac Ninh province, Vietnam*. (EEPSEA, IDRC Regional Office for Southeast and East Asia, Singapore, SG.) ISBN 981070948X

FERNANDEZ, J E. 2007. Resource consumption of new urban construction in China. *Journal of Industrial Ecology*, Vol. 11, 99-115

FONG-SAM, Y. 2014. The Mineral Indsutry of Vietnam. *USGS* https://minerals.usgs.gov/minerals/pubs/country/2014/myb3-2014-vn.pdf

GENERAL STATISTICS OFFICE OF VIETNAM (GSOV). 2018. Statistics Database. [cited 2/2/2018]. http://www.gso.gov.vn/Default_en.aspx?tabid=766

GLOBAL CEMENT. 2012. Cement in Vietnam. [cited 3/2/2018]. http://www.globalcement.com/magazine/articles/687-cement-in-vietnam%5d

GLOBAL CEMENT. 2018. Production continues to soar in February 2018 in Vietnam. Global Cement [cited 2/3/2018]. http://www.globalcement.com/news/item/7228-production-continues-to-soar-in-february-2018-in-vietnam

HUANG, T, SHI, F, TANIKAWA, H, FEI, J L, AND HAN, J. 2013. Materials demand and environmental impact of buildings construction and demolition in China based on dynamic material flow analysis. *Resources Conservation and Recycling*, Vol. 72, 91-101. <Go to ISI>://WOS:000317172600011

http://ac.els-cdn.com/S0921344912002273/1-s2.0-S0921344912002273-main.pdf?_tid=1a92fbd8-437b-11e6-8032-00000aab0f26&acdnat=1467810848_7398ddfe1fe062265f4c8f042da0b4db

IWATA, S. 2007. The Comprehensive Urban Development Programme in Hanoi Capital City of the Socialist Republic of Vietnam (HAIDEP). *Final report, JICA, Hanoi*

JICA, AND HANOI PEOPLE'S COMMITTEE. 2007. The Comprehensive Urban Development programme in Hanoi Capital City of the Socialist Republic of Vietnam (HAIDEP). *Japan International Cooperation Agency (JICA)*

KLUFALLAH, M M, NURUDDIN, M F, KHAMIDI, M F, AND JAMALUDIN, N. 2014. Assessment of carbon emission reduction for buildings projects in Malaysia-A comparative analysis. *E3S Web of Conferences*, EDP Sciences, Vol. 3.

LEDUCQ, D, AND SCARWELL, H-J. 2018. The new Hanoi: Opportunities and challenges for future urban development. *Cities*, Vol. 72, 70-81

NHANDAN. 2011. Hanoi's population to reach 8 million by 2020. [cited 3/3/2018]. http://en.nhandan.com.vn/society/item/1706702-.html

PERKINS EASTMAN. 2011. Hanoi Capital Master Plan to 2030. [cited 20/3/2018]. http://www.perkinseastman.com/project_3407114_hanoi_capital_master_plan_to_2030

TRIHAMDANI, A R, KUBOTA, T, LEE, H S, SUMIDA, K, AND PHUONG, T T T. 2017. Impacts of Land use Changes on Urban Heat Islands in Hanoi, Vietnam: Scenario Analysis. *Procedia Engineering*, Vol. 198, 525-529. http://www.sciencedirect.com/science/article/pii/S1877705817329533

UNEP. 2017. UNEP World Data. [cited 2/3/2018]. https://uneplive.unep.org

VAN DER VOET, E, PETAVRATZI, E., VAN OERS, L. AND GUNN, G. . 2017. Integrating data, methods and expert knowledge to inform mineral intelligence. http://www.mica-project.eu/wp-content/uploads/2016/03/D3.4_D4.4_Integrating-data-methods-and-expert-knowledge-to-inform-mineral-intelligence.pdf

VAN VU, N. 2016. ECONOMIC GROWTH OF VIETNAM IN 2011-2013. *Vietnam Social Sciences*, 10. http://www.vjol.info/index.php/VSS/article/viewFile/23657/20220

VIET NAM NEWS. 2017a. Sand prices see sharp increase. Biz Hub [cited 2/3/2018]. http://bizhub.vn/news/sand-prices-see-sharp-increase_285412.html

VIET NAM NEWS. 2017b. Sand prices see sharp increase. Viet Nam News Biz Hub. [cited 1/2/2018]. http://bizhub.vn/news/sand-prices-see-sharp-increase_285412.html

VIETNAM CEMENT ASSOCIATION. 2017. Cement market Quarter 1 Vietnam Cement Association. [cited 2/3/2018]. http://ximang.vn/bien-dong-thi-truong/thi-truong-xi-mang/quy-i-san-xuat-va-tieu-thu-xi-mang-tang-nhe-9507.htm

VIETNAM NEWS AGENCY. 2017. Vietnam faces severe sand shortage. Vietnam News Agency. [cited 2/3/2018]. http://english.vov.vn/economy/vietnam-faces-severe-sand-shortage-349192.vov

VIETNAM.NET. 2017. Price of Vietnam sand rises due to limited supply. [cited 2/2/2018]. http://english.vietnamnet.vn/fms/business/178911/price-of-vietnam-sand-rises-due-to-limited-supply.html

VIETNAMNET. 2017. Sand Shortages delays transport projects. Vietnamnet Bridge. [cited 3/3/2018]. http://english.vietnamnet.vn/fms/society/180027/sand-shortage-delays-transport-projects.html

WORLD BANK. 2018a. Atlas of Sustainable Development Goals 2018: From World Development Indicators. http://datatopics.worldbank.org/sdgatlas/the-world-by-income.html

WORLD BANK. 2018b. Data for lower middle income, Vietnam, Development Indicators. *World Bank*. https://data.worldbank.org/?locations=XN-VN

WORLD BANK DATA TEAM. 2016. New country classifications by income level, World Bank. **2018**.