UNDERSTANDING RELATIONSHIP BETWEEN RESOURCE CONSUMPTION AND DEVELOPMENT ACTIVITIES IN PHUENTSHOLING

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Abstract

It is good to know about the developmental activities going on but at the back of the mind, there is a concern about for how long the available natural resource would contain. Bhutan being a small country, there are only limited resources available for which it should be used efficiently. With increase in population, the migration of people from rural to urban areas in search of better opportunities has increased over the year which eventually demands more housing in urban areas. The research is being focused at Phuentsholing as it is one of the highly populated regions of the country.

This research indicates some relationship between natural resource consumption mainly for building construction and developmental activities which is required to alert people about the available natural resources. It is an important matter to be taken into consideration for a sustainable development.The natural resources available in the study area for building construction addressed are sand, stone and timber. It is based on analysis and interpretation of annual data collected from various agencies of Phuentsholing like Phuentsholing Thromde, Natural Resource Development Cooperation Limited and Department of Forests and Park Services.

The production and consumption pattern of natural resources has been illustrated followed by technical intervention to reduce the consumption of natural resources by urban scaling method and material flow analysis of the resources. After completing the analysis, the project aims for the achievement of sustainable cities through urban scaling approach and responsible production and consumption of natural resources through material flow analysis.

Key Words: *Sustainable development, construction, natural resources, urban scaling, material flow analysis.*

1. INTRODUCTION

Sustainable Development aims at addressing key global problems to create a sustainable world for all. While considering objectives of sustainable development, the inter-dependencies between some of them remain uncertain, meaning difficulties may emerge in achieving all the objectives at the same time. A key example of this is the relationship between social development and resource consumption, and its impact on humanities. Considering this relationship is important in order to recognize the type of services and best practices that are currently used to meet basic human needs. This understanding is critical to allow for systemic creation within the country's carrying capacity.

Holding the essential relationship above in mind, urban development has been taking place around the world and Bhutan is no exception. It is seen that there has been a drastic increase in the construction activities over the past decades which ultimately affects the social development. With more developmental phase in place, it is of no doubt to see the rapid consumption of resources in the country, particularly natural resources.

In recent years, there has been hasty intensification of the construction industry in Bhutan. Similar to most developing countries, the construction industry being a part of social development activity plays a leading task in the socioeconomic development of the country. Construction of buildings is one of the reasons for the growth of construction sector. It is anticipated that the construction industries will further increase in future as the country is rapidly developing.

The growing need of the buildings in urban areas with limited quantities of natural resources available results a big challenge in fulfillment of sustainable development. Knowing the development rate and resource consumption in preset scenario, it is important to have optimum development with consistence within the limits.

Hence, the study was opted in order to understand the resource consumption rate of natural resources with development level. Further to improve the flow of construction material with proper usage of resources and controlled rate of extraction.

1.1 Problem statement

Excessive extraction of natural resources such as sand, stone and timber to meet the requirement of the alarming increasing rate of constructions and lack of proper scale to measure the rate of resource consumption in construction which may lead resource crises in near future.

1.2 Aims and Objectives

The aim of this research is to achieve sustainable development through reduction in consumption of natural resources. To achieve the aim of this study following objectives are being employed:

i. Compare the resource consumed in construction with development level.
ii. Develop a relation between growth rate of building and population of study area by urban scaling method.
iii. Formulate a flow of natural resources within a system (useful life of building) by material flow analysis.
iv. Achieve Sustainable Cities
v. Achieve responsible production and consumption of natural resources.

2. METHODOLOGY

Different methodology were adopted to achieve the aim and objectives of this study. Literature review has been conducted all the way through the project to get information and also to develop ideas related to the study. It consists of journal papers and articles of related topic and findings. After some reviews have been done the natural resource for building construction available in the study area has been identified. In order to understand the resources consumption pattern of the study area data on resources consumption and production of identified natural resources were collected and quantified. To obtain urban scaling equation, data on population, type of settlement, infrastructures (buildings), average height of infrastructure, within the study area are collected.

Thereafter urban scaling method is employed for finding the above mention equation known as urban scaling equation. This equation gives a relation between urban attributes and growing population. The study was further made employing material flow analysis method using STAN software on what percentage of new resources can be reduced if 70% of current amount of C&D waste produced are recycled.

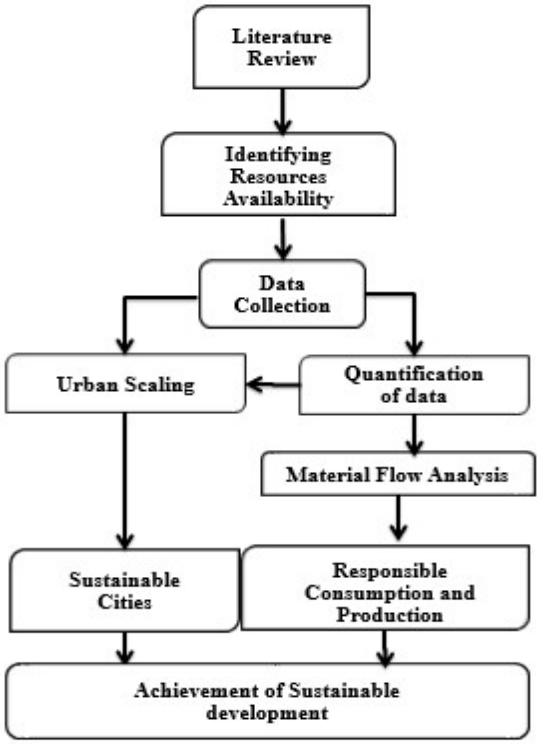

Figure 1: Methodology employed for the study

Thereby sustainable cities was achieved through urban scaling approach and responsible production and consumption of natural resources by material flow analysis.

3. ANALYSIS AND NTREPRETATION

3.1 Identifying natural resources available for construction and data collection

Natural resources available in the study area as a raw material for the construction are sand, stone and timber. As per the requirement of the study various data are collected including population data, type of settlement, infrastructures (buildings), average height of infrastructure, rate of natural resource consumption and production in Phuentsholing Thromde from the sources such as MoHCA, Phuentsholing Thromde, NHDCL and DoFPS, MoAF (Table 1: Data of production and consumption of resources).

3.2 Data of Natural Resource Production and Consumption of Phuentsholing Thromde.

Production and consumption of resources						
	Timber in cum		Stone in cum		Sand in cum	
Year	Production	Consumption	Production	Consumption	Production	Consumption
2012	2137.71	2264.30	62659.42	62537.09	71752.00	74240.00
2013	1827.03	1724.64	36920.11	38167.16	56113.05	57474.05
2014	1406.51	1476.22	41717.75	42114.05	40870.66	35030.66
2015	1433.31	1598.71	54367.58	54489.90	32741.50	28421.50
2016	1224.63	1271.88	111457.36	111457.36	52824.00	55730.00
2017	1014.93	1009.35	102665.39	96623.72	48553.00	53076.00
2018	1757.45	1653.47	205904.54	211945.20	34587.40	34587.40
2019	1111.25	1071.04	178086.32	178836.14	31825.86	33833.60
2020	1026.20	947.20	200620.80	201496.10	27730.84	29243.00
2021	920.96	823.36	223155.20	224156.20	23635.82	25419.62

Table 1: Data of production and consumption of resources

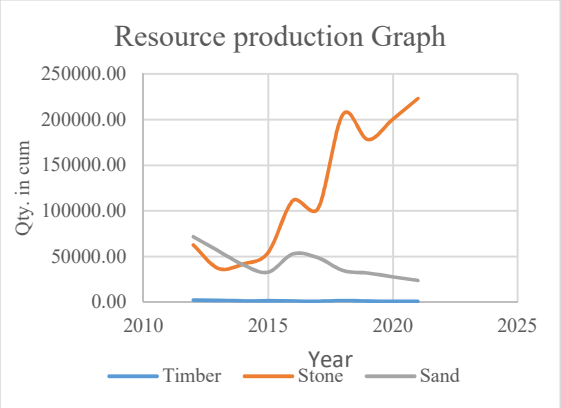

Figure 3: Resources consumption Graph

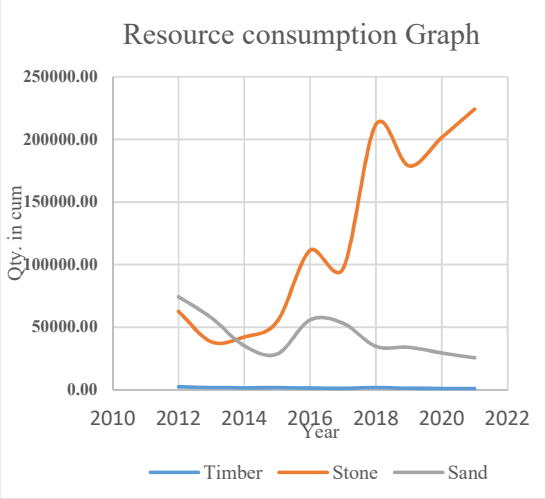

Figure 2: Resource production Graph

The data collected is plotted into graph for production and consumption against year. The variation on decreasing order over the year represents that the resources produced from the area is decreasing. Hence the resources consumed from the area are less and have to depend on the resources produced from other areas (Ipsita Satpathy, Jai Kishan Malik, Nitish Arora, Dr. Shilpi Kapur & Bhattacharjya, 2016).

The variation on increasing order over the year represents the production of resources from that area is being sufficient for the consumption purpose and meets the demand. There is no need to depend on other place's production; instead there is excess that can be supplied and used by other places where there is lack of resources.

3.2.1 Data of Resource Consumption by Buildings in Phuentsholing Thromde.

The total volume of sand, stone chips and stone consumed in all the buildings were difficult to find as there are different varieties of: 1) Building sizes 2) Building heights and 3) Structural component sizes.

Natural Resources Used in Building Construction in Phuentsholing						
Years		2014	2015	2016	2017	2018
Particulars	Unit	Quantity				
Timber Consumption	cu.m	58.05	428.09	138.53	229.58	463.24
Sand Consumption	cu.m	616.60	2465.40	5547.15	10888.85	25270.35
Stone Consumption	cu.m	460.80	1843.20	4147.20	8140.80	18892.80
Stone Chips Consumption	cu.m	1232.70	4930.80	11094.30	21777.70	50540.70
No. of Building		6602	6614	6641	6694	6817

Table 2: Natural resources used in building construction in Phuentsholing.

So the assumptions were made to overcome the difficulties faced and for easy calculation. Without the assumptions, it was not possible to get the idea about resource consumption in the study area (Chhokar & Dixit, 1992). An average height of a building existing in study area is taken into account after obtaining the data on the heights of the building. With an appropriate mix ratio, the consumption of each resource is calculated. With increase in number of buildings, there is no doubt

that the consumption of resources in building is increasing over the year.

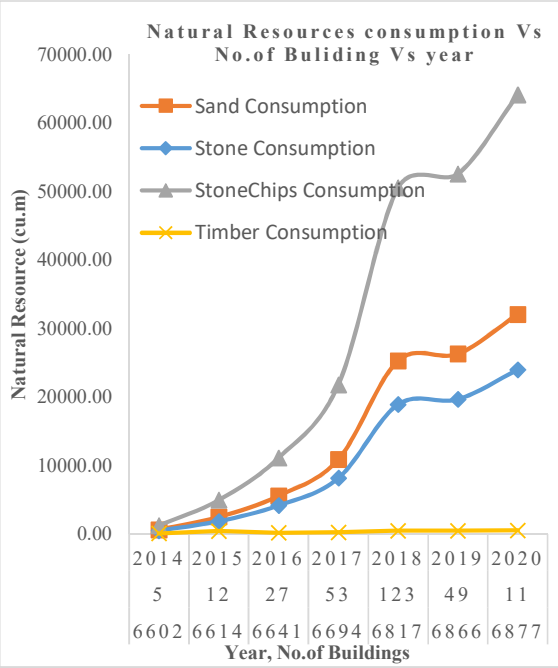

Figure 4: Graph showing relation between natural resources consumed and No. of building over the year.

3.3 Urban Scaling

It is a scaling through which city size variation as per increasing number of population is regulated with an objective structure for sustainable urban development. Urban scaling law notes that the relationship between urban attributes and population is very well described by the power-law $Y = Y_0 * P^{\beta}$, thus the urban attributes Y have a power-law relationship with urban population P, where Y_0 is a specified constant, and β is a scaling exponent (Bettencourt, Lobo, Helbing, Ku, & West, 2006). The scaling exponent β has a vast range of urban properties that fall into three universal categories. Urban scaling laws have been widely applied to the study of urban governance, planning policies, urban structures and strategies for the environment.

3.3.1 Urban Scaling Data

Various data on population, settlement type, and approximate numbers of building in study area are collected. Since there is no concrete data, whatever data obtained is used at its best, making some assumptions.

The graphs plotted using above data shows that the population and number of building are

Urban Scaling Data		
Year	No. of building	Population
2014	6602	31513
2015	6614	32157
2016	6641	32800
2017	6694	33444
2018	6817	34100
2019	6827	34736
2020	6877	35382

Table 3: Urban scaling data:

proportional, both increases over year. It is difficult to control the increasing population of urban areas.

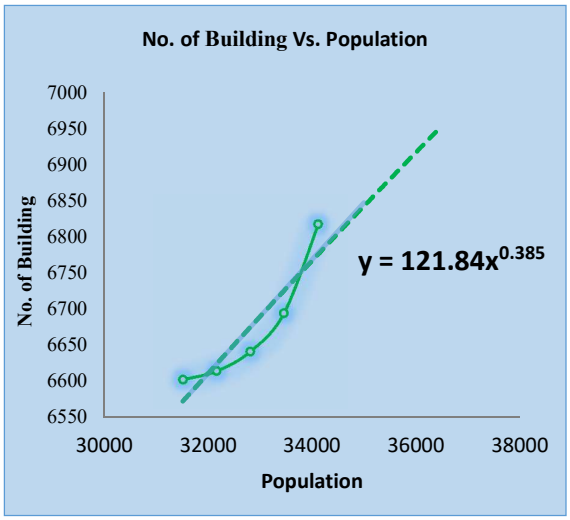

Figure 5: Number of building vs Population

Hence there is no way that the existing buildings are sufficient in future. The urban scaling equation is obtained from the above graph which relates the number of buildings being constructed in Phuentsholing Thromde and its population. $Y(N) = 121.84\ N^{0.385}$. Here, Y(N) is the number of building which is an urban attribute and N is urban population. The scaling exponent beta ($\beta = 0.385$) obtained is less the one which indicates a sub linear regime associated with infrastructure variables that is number of buildings built in Phuentsholing.

3.3.2 Sustainable City

Sustainable city is characterized in engineering when resources are most efficiently utilized. There are many approaches to achieving sustainable cities and making cities more sustainable would rely on a similarly wide range of

actions. This research is one of many approach to achieve the sustainable city through urban scaling.

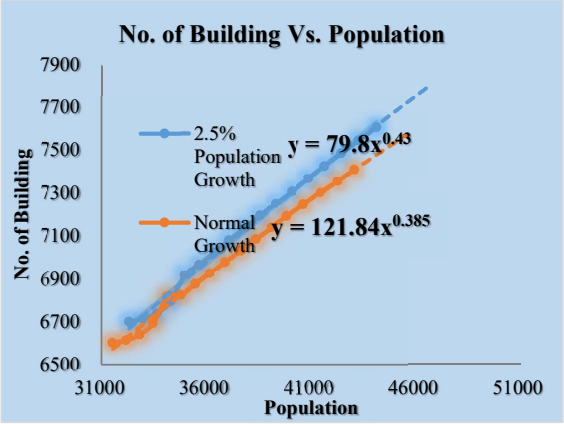

Figure 4: No. of building Vs Population for Sustainable city

Current population and building growth rate of Phuentsholing Thromde is 1.92% and 0.8%, respectively. The optimum population growth rate and buildings in Phuentsholing Thormde is kept at 2.5% and 1.5% respectively. Therefore, for Phentsholing Thromde urban scaling equation obtained through the study are, $Y(N) = 121.84\ N^{0.385}$ for current growth rate and $Y(N)=79.8N^{0.43}$ for optimum growth rate.

3.4 Material Flow Analysis

3.4.1 Background of Material Flow Analysis

Material flow analysis (MFA) is a comprehensive evaluation of material flows and stocks within a space- and time-defined framework. This binds a materials' origin, paths, intermediate and final sinks. MFA's most important application is to identify the depletion or accumulation of material stocks at early enough to either take countermeasures or promote further build-up and future use.

3.4.2 STAN (Substance Flow Analysis) Software

STAN is a freeware which helps to perform material flow analysis in accordance with Austrian standard ÖNorm S 2096, Material flow analysis-waste management application (Cencic & Rechberger, 2019).

For our MFA, the import data will be the stocks or the quantities of layers i.e., Sand, stone and timber in cu.m.

3.4.3 Consumption Pattern of Resources

The graph below shows how consumption of all natural resources is changing while no of buildings are increasing each year in Phuentsholing Thromde. It is clear that every year the number of building is increasing leading to increase in resources consumption. This increasing buildings leads to increase in C&D waste production. These C&D waste, which otherwise goes to landfill can be recycled and reused so that it can help decrease

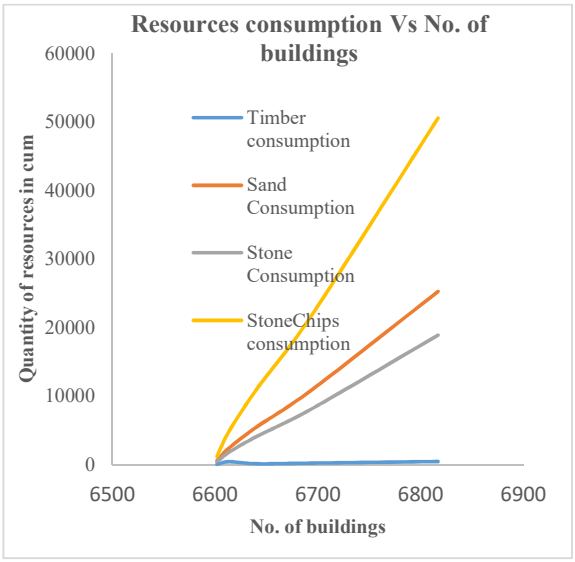

Figure 7: Graph showing the consumption pattern of Resources

in extraction of new resource.

3.4.4 Material Flow Analysis of Construction Sector

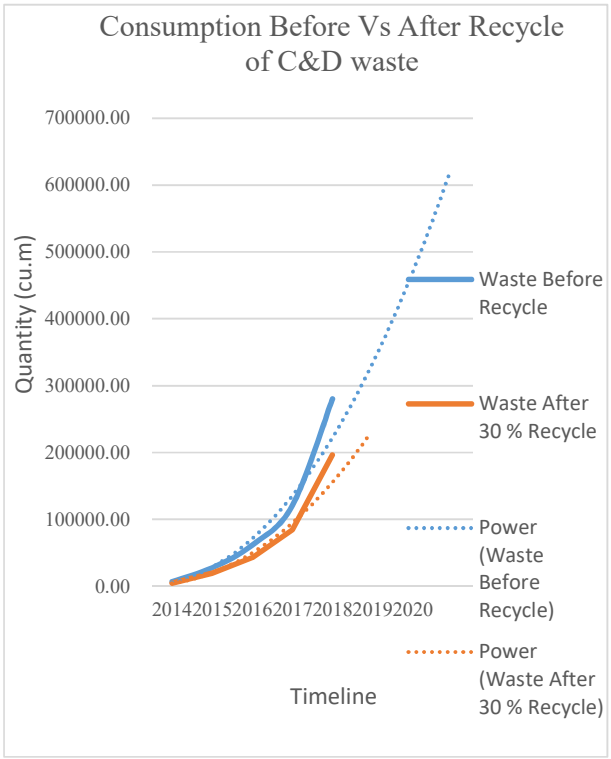

Figure 8: Graph Showing C&D waste before and after recycle

It is important to understand the flow of natural construction materials in the construction sector to know how efficiently they are being used. Material flow analysis offers an ability to determine C&D waste flow that occurs during construction and at the end of buildings life (Islam, Hassan, Yuniarto, Uddin, & Salmiati, 2019). The table below shows how much resource we can save from recycling 70% of the demolished waste. Quantity of waste that goes to the landfill is increasing over the time. The graph is plotted using these data.

In the graphs above, blue and orange line shows C&D waste going to landfill before and after 70% of the waste recycled, respectively. The fact that not all resources after demolition can be recycled and reused is due to certain percentage loss in the process. The resources generated from C&D waste can contribute to certain percentage in the construction sector that can help reduce the quantity of consumption of new reserved resources. It will also help producing less waste in landfills (Tam, 2011).

3.4.5 Responsible production and consumption of natural resources

Consumption before and after 70% recycle of C&D waste in Phuentsholing Thromde		
Years	Consumption Before Recycle	Consumption After 70% Recycle of C&D waste
2014	6887.83	4821.48
2015	27738.87	19417.21
2016	61587.79	43111.45
2017	120852.2	84596.54
2018	280398.76	196279.13

Table 4: Consumption before and after 70% recycle of C&D waste in Phuentsholing Thromde

For responsible production and consumption of natural resources, the main aim is to minimize the consumption of natural resources at the source by recycled C&D waste. The rate of recycling C&D waste is other developed countries is about 80%. So, up to 70% of the C&D waste is considered to be recycled and MFA was conducted based on the same. It does not cover on how and where the waste are being reused (waste stone used in other construction sectors like in soling) but it targets to reduce the consumption of new natural resources through recycling 70% of C&D waste.

4. CONCLUSION

Demand for natural resources in the construction sector is increasing rapidly with the increasing number of buildings. One cannot produce all available natural resources to meet this projected growth. There need to build sustainable city. It is a city characterized in engineering, when resources are most efficiently utilized. This research have proved one most effective way to achieve this through limiting the number of buildings coming up in a year to some specified range in relation to the number of population in that area. It is done using the equation known as urban scaling equation. For the Phentsholing Thromde urban scaling equation obtained through the study are, $Y(N) = 121.84\ N^{0.385}$ for current growth rate and $Y(N)=79.8N^{0.43}$ for optimum growth rate for Phuentsholing Thromde. Where, Y(N) gives the number of building and N is the number of population in the area. Urban scaling equation is used in the determination of future upcoming number of buildings achieving sustainable consumption pattern of resources in relation to growing population

Through the research conducted in Phuentsholing Thromde, if 70% of C&D waste were recycled and reused then the consumption pattern of natural resources would be greatly reduced. In the year 2018, consumption of stone, sand and timber in Phuentsholing city were 352346.47m^3, 136552.97m^3 and 3304.8 m^3, respectively. Through material flow analysis, when 70% of C&D were recycled and reused, fresh resources consumed were reduced to 105703.94m^3, 40965.89m^3, 991.44m^3, respectively. Therefore, the C&D waste should not go directly to landfill as a waste. Some percentage of useful material need to be recycled. It will greatly help in reduction of certain percentage of production of new resources and also the waste going to landfills thereby achieving sustainable development for long run.

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