Development of a Recycling System Policy for Construction and Demolition Waste Materials with Applications in Libya towards Sustainable Development

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Abstract

Construction and Demolition Waste (CDW) materials are presently put in landfills (henceforth, Landfill-Designated Waste). At the same time, many developing countries, particularly in Africa, suffer from a lack of proper management of suitable materials for road construction, mainly old concrete, brick, asphalt, gravel, and angular sand. CDW is significant because it may be fully or at least partially reused in new construction projects, saving valuable and non-renewable resources. In addition to the depletion of natural resources, the disposal of CDW causes clogging of disposal sites. Due to the absence of a recycling and reusing policy, there are no alternatives to these disposal sites where CDW piles up. The three challenges to recycling are: 1) landfill space which is cheap or free; 2) social norms and education surrounding recycling; and 3) waste is perceived as garbage, and therefore of lesser quality. By quantifying how landfilling CDW represents an increase in environmental liability and a problem for the future, this research discusses the waste of the potential value of the material and how existing and scarce resources might be protected. Thus, CDW is a liability that can be turned into a valuable resource by using System Dynamics (SD) concepts. In addition, SD presents a convenient framework to monetize the value of the recycled waste. This framework is based by characterizing CDW and then on reusing it. The results of the model provide an innovative needs-based recycling policy to manage CDW. The scope of the study is at the national level, focused on Libya but generalizable to developing countries with comparable climatic, social and cultural features. Validation in this study relies on three things: 1) verifying that the units that are input into the model are correct; 2) comparing the results with successful previous studies; 3) using one specific and very common building design. This needs-based approach regarding required construction materials relies on estimates of future material needs, from either new or recycled sources, for both new and rehabilitation projects. This assessment is based on infrastructure needs, population growth rates, GDP, and cement production and consumption

Specific Issues

The construction of new projects, renovation, and demolition wastes from infrastructure development can have a great impact on the environment, and on energy and material consumption if they are not regulated (Marzouk & Azab, 2014)

The general unwillingness to accept second-hand or recycled materials creates a lower demand for recovered or recycled materials on the market. Nonetheless, the end goal of the project is to develop a sustainable model of waste management that is appropriate to the social and physical environment as well as to the economy of a country such as Libya. The recycling of materials helps to reduce landfill pressures.

During the design stage of construction projects, sustainability principles for holistically integrating material selection must be incorporated. There is a lot of research in this area but there are still many obstacles to incorporating sustainability concerns in material selection in order to make the appropriate decision.

Objectives to Establishing a Sustainable Framework Research

The main goal of this study is to devise a framework and methodology for a developing nation to establish a recycling policy for construction materials from a socially, economically and environmentally sustainable perspective.

The specific objectives of this research are:

1) Identify and characterize existing CDW at the national and city levels in a developing country such as Libya; these must comply with relevant and generally accepted guidelines and standards in order to establish a reliable and dependable accounting of potential material assets for different reuse needs.
2) Propose an adapted recycling policy framework for Libya and similar developing countries.

(Nazirah Zainul Abidin (2010) defines sustainable construction as an approach towards the future in which the needs of development are balanced with a duty to protect the natural environment, public health, and economic security; i.e., the goal is to develop places that are prosperous for public and environmental health, and work.

Methodology

The application of SD in this study relies on the VENSIM PLE software. This program has a graphical user interface (GUI) that is useful to help the user design and test a system dynamics model.

The model aims to reproduce the Reference Behaviour Patterns (RBP) of the roadwork construction sector as it pertains to buildings that will be reused, recovered, and recycled into base and sub-base materials for road construction. Once these are properly defined, it will be possible to consider how policies and community behaviour affect the goal of using recycling to move towards zero landfill waste.

What distinguishes this research is that it introduces the modelling of cement production and consumption values pertaining to buildings. (Ali et al., 2016) points out that cement is crucial to making concrete and that over 97% of Libyan construction employs cement (Ngab, 2007). For this reason, the first step is to use a statistical analysis of cement production to make an estimate of concrete in Libyan CDW. In other words, it can be easily determined how much cement is produced in or imported into the country; it can also be determined how much of this goes into construction in the country; because this holds true for the other construction materials, the composition of the CDW can be derived. Such an analysis is possible because there are good records of data pertaining to cement use, but it is also necessary to use such an analysis because fieldwork, that might otherwise be conducted, is not possible due to the political situation in Libya; there is also a general lack of consistent data on the kind and quantity of construction projects. Another way to qualify the data is by using a per capita comparison with countries that have similar social and economic characteristics, i.e. ones that derive their primary economic strength from petroleum exports and that have a similar cultural makeup.

Using Cement Consumption to Estimate Libyan CDW

In the 1970s, Libya was considered the highest per capita consumer of cement, averaging about six million tons each year (Ngab, 2007). From 1992 through 2006, the consumption of cement went up markedly from about four million tons per year to about seven million tons per year; this was because of a large number of government construction projects. Prior to 2011, the government had initiated some projects to increase domestic cement production, aiming at bringing it up to about 13.5 million tons by 2010 (AUCBM, 2007); Libya was in fact producing about ten million tons annually. Libya does not produce enough cement to fulfill its own needs and therefore has imported much of this cement from neighbouring countries, such as Egypt, Tunisia, and Turkey (Ali et al., 2016). There had been plans to raise the levels of cement production to as much as 15 million tons before 2011; in fact, the Libyan government had issued permits to several foreign corporations to help make up the shortfall in cement production.

Table 2: Construction developments that were in process or that were planned up until 2010 (Ali et al., 2016)

Company	*Project type*	*Type of cement*	*Planned production capacity under study**	*Planned production capacity under construction**	*Production started*
Libyan cement Fattaih Factory	A new production line	White	190	-	2008
Libyan cement Fattaih Factory	A new production line	White	-	-	2008
Libyan cement Fattaih Factory	A new production line	Normal	950	-	2008
Libyan cement Hawari Factory	A new production line	Normal	1330	-	2008
Libyan cement Benghazi Factory	Improving production line	Normal	475	-	2008
Ahlia Cement Factory Zliten	A new production line	Normal	-	900	2008
Ahlia Cement Factory Libdeh	A new production line	Normal	-	1500	2008
Ahlia Cement Factory Koms	A new production line	Normal	-	1500	2008
Orascom Group	New factory	Normal	-	-	2008
Total (8 projects)			**2945**	**3900**	
Total of expansions: 6845 *Thousands of tonnes per year					

Simulation and Policy

The Average GDP growth Rate and Fraction of GDP Going to Cement Production are critical factors in waste generation as shown in Figure 3.0. The results are shown in Figure 3.1, expressed as the following equation:

$$\boldsymbol{Fconcret} = \boldsymbol{Pconcret} * (1+\Delta\ \mathrm{GDP}) * (1+\Delta\ \mathrm{Population})$$

Where:

$\boldsymbol{Fconcret}$= future production of concrete waste, $\boldsymbol{Pconcret}$=Present production of concrete waste.

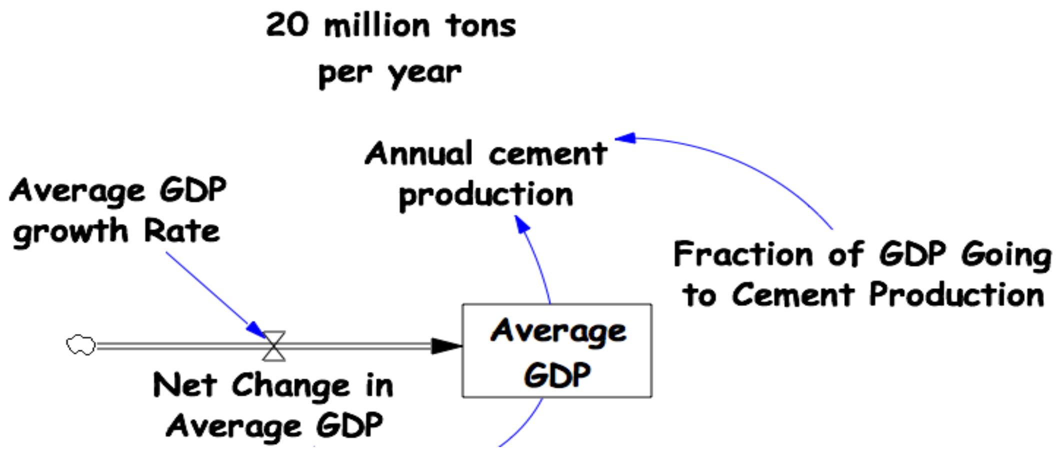


Figure 3.0 shows the relationship between Annual Cement Production, Average GDP, and the Fraction of the GDP that goes to cement production.

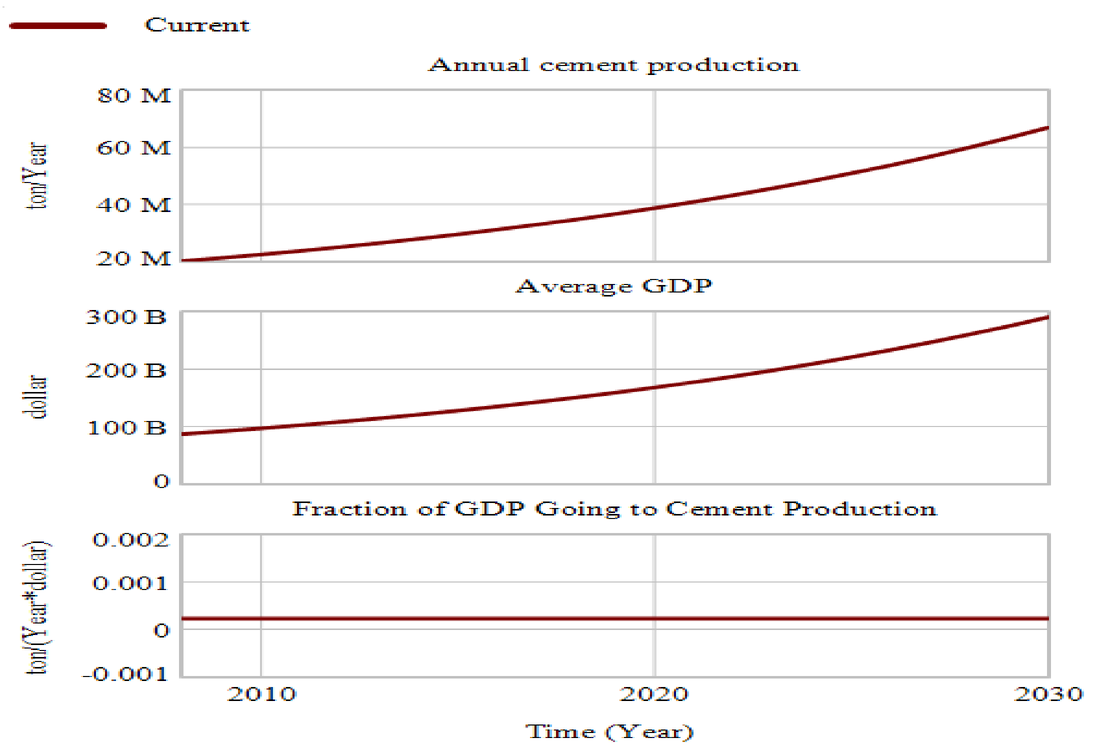


Figure 3.1 shows the output of the scenarios between Annual Cement Production, Average GDP, and the Fraction of the GDP that goes to cement production.

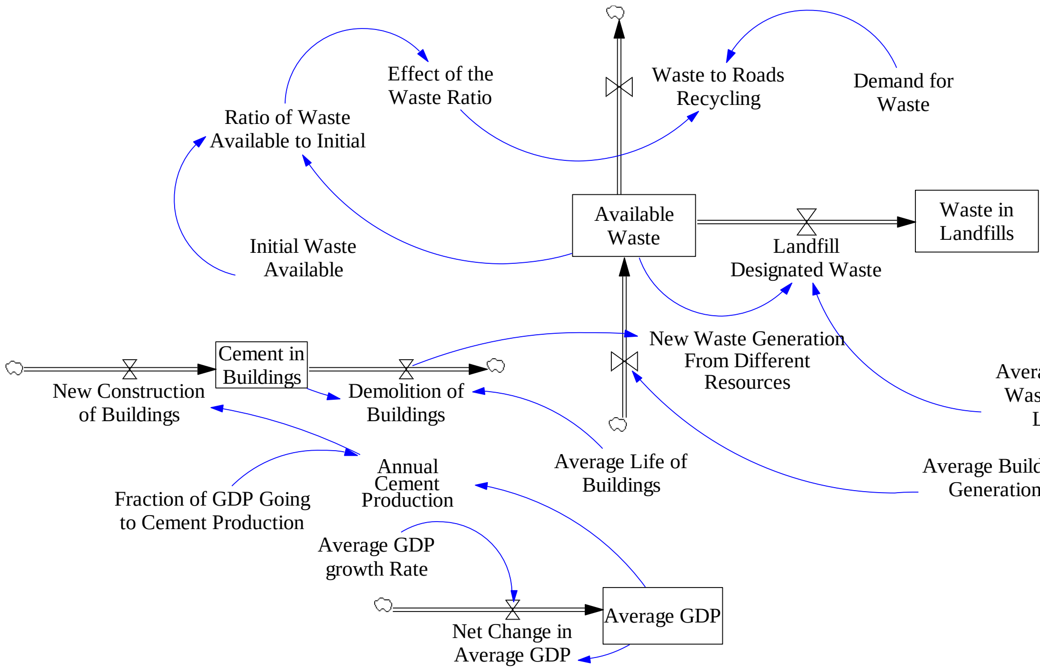
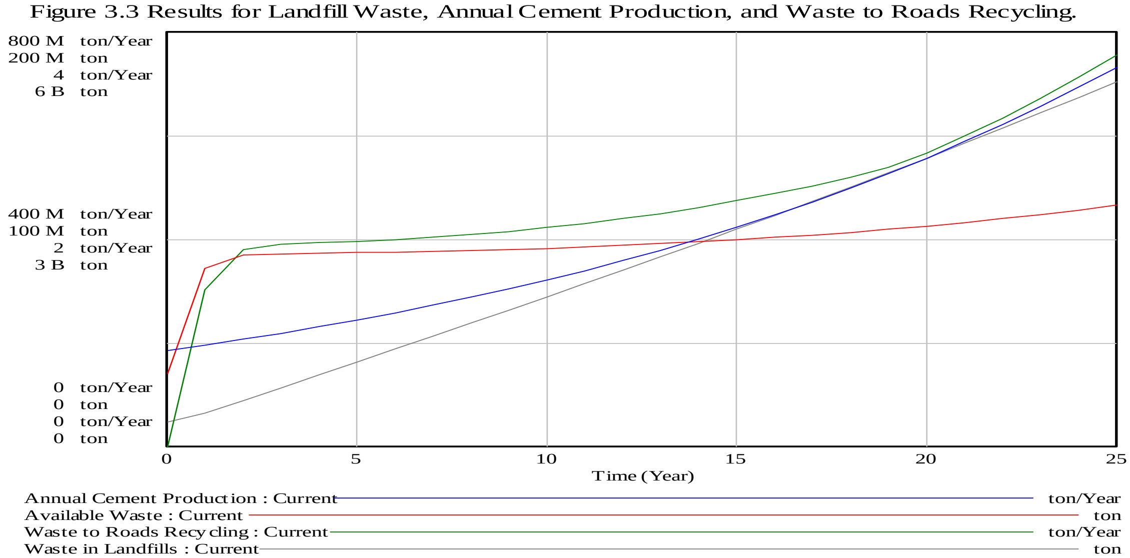
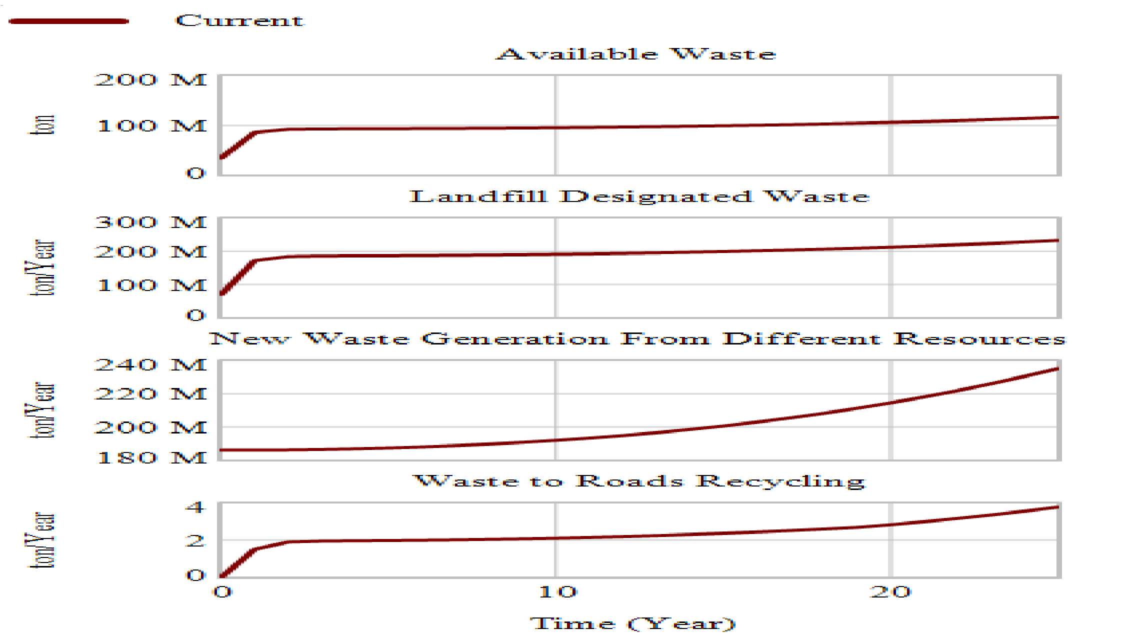


Figure 3.2 Shows the Model Benchmark for CDW Management and the Flows and Stocks with the Important Factors

The data will be aggregated so that the model remains usable. As such, all recyclable materials will be counted together; the population and degree of urban development will determine the total user base; for the purposes of the model, this user base is assumed to be as active as possible given the facilities available. If such aggregation affects the results of the model, it is hoped that it is minimal and that the trade-off is reasonable, considering the scope of the project.

Figure 3.3 Results for Landfill Waste, Annual Cement Production, and Waste to Roads Recycling.





Validation and Verification

Validation and verification gets easier as the model develops because these factors build on each other. These can be summarized into three categories, each of which includes highlights of the validation efforts that were conducted. Validation in this study relies on three things: 1) verifying that the units that are input into the model are correct; 2) comparing the results with successful previous studies, for example (Bala, 2017;Mashayekhi, 1993), 3) Using one specific building, the specifications of which are discussed below. The present study successfully executed the first two validation steps.

Conclusion

The general trend is that, as the income of a community grows, this leads to the increase in building projects, and CDW. Around the world, there are a number of different methods of disposal; the most common are landfilling and open dumping. Landfilling is very common in industrialize countries but open dumping is the most common in countries like Libya because there is little to no cost associated with it and it usually does not have any governmental organization. In this case, the outskirts of urban areas and natural geographic areas such as valleys are used for this. If recycling is ever to be economically attractive for many small governments, there must be a recovery phase, wherein useful materials can be extracted, and subsequently used in the base and sub-base for future roadwork construction.

Figure 3.3 shows the results of the model illustrating how the Landfill-Designated Waste increases steadily over time. The behaviour of the Annual Cement Production shows the same results; this is an important indication and implies that there is a significant relationship between Annual Cement Production and Landfill-Designated Waste. This will help the stakeholders make a suitable strategic plan for recycling CDW. As shown in figure 3.1, in 2005, the first year shown in the simulation, Libya had an annual cement production of about two million tons; in the same year, it had an annual GDP of US$100 billion; because the GDP growth is related to population growth, with a population estimate for 2030 of about 7 million people, the GDP is about. The construction sector in cities is tied to the grown rate of the

GDP; the migration of populations into cities also stimulates construction. The outcome of more construction is the use of more cement, and the production of more waste. Therefore, more waste management infrastructure is needed. Without recycling and reusing waste, there are two primary environmental effects: a scarcity of natural resources; landfill sites being clogged.

There is a growing crisis in Libya with regard to CDW because many cities are affected. This is a particular problem because there is a lot of CDW that still has not been collected from the 2011 revolution. There has also been a lot of economic growth since then (especially in 2012), and this inevitably leads to more CDW. This problem is not only a problem for Libya but also for similar countries, such as Syria and Iraq. The present model can be used to help solve this problem, and includes aspects such as Life-Cycle Cost Analysis (LCCA).

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