Regional Model of Smart Construction Waste Monitoring: Household Base Framework in Central Java-Indonesia

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Abstract
The growth of infrastructure development is currently increasing rapidly in Indonesia. Beside government policy through their procurement in national, provincial and local level, it is also driven by private sector and per capita as of economic growing and increasing population. In the process physical development, several mixture of material such as stone, cement, sand, demolition material are often left over and discharge. Today Indonesia government will issue construction and demolition waste guideline to make more green and environmental sound. One of the basic problem founded was concerning to the development of model to estimated then monitored construction generation in rural, urban or in a strategic region. Moreover, in the era of digital as known as revolution industry 4.0, an automatic system of monitoring, known as smart monitoring of the construction waste generation is very importance to build. The purpose of this study was to build regional model of smart construction monitoring in Indonesia. The basic method to build the regional model is by utilized an index approach, and combined by using GIS to build automatic information delivery system from rural, urban or region to the central system. This study is then choosed Central Java Province for more detail model development. The study founded 7 (seven) pattern of construction waste generation. The extreme condition founded in Grobogan, Purworejo and Kebumen at which for decade 2000-2014 the degree is waste generation always decrease. In Addition, in central Java Province, this study founded three characteristic of regional model of construction waste as follow: (1) Region with high level of construction waste degree; (2) region with moderate level of construction waste degree; and (3) region with low level of construction waste degree.
1. Introduction

Construction waste is a residual from construction and related activities during development, maintenance, rehabilitation and demolition of Infrastructure and facility. Cheng and Ma defined construction and demolition waste as waste that generated by new construction, renovation, demolition of buildings, roads, bridge and others infrastructure facilities [1]. Moreover, according to the infrastructure classification from Grigg [2], the construction and demolition of waste can be generated from development process and maintenance of housing, park, port and transportation system, energy system, water and waste water services. Construction and demolition waste also can be arisen from natural and technological failure disaster [3].

Today, construction waste management and related issue increasing world wide. It is not only associated with green construction consideration but also driven from community understanding, intention, awareness to increase urban rural environmental health and safety to ensure the pathway of sustainable development. Indonesia government conducted the construction waste management refers to Indonesia law Number 18 year 2008 especially in article 2 paragraf 4, 5, article 23 paragraf 1, 2 [4]. Several researchers and practitioners state that to achieve green and minimize construction waste, the management guide line should cover in each stage of development such as during planning, design, procurement, construction, maintenance and demolition [5, 6, 7]. They state that the basic issue of the management is the availability of formula or model for estimation construction and demolition waste generation [6]. Moreover, construction waste must be monitored since the management is not only during construction process but also for ensure that there is no impact before, during and after construction which associated to maintenance and demolition stage.

This study goal is to proposed basic model to estimate and monitor construction waste generation in Indonesia. The model to estimate construction and demolition waste has been conducted, such is by Tanikawa et al [8], Katz Baum [9] and Masudi et al [10] made a review of the model estimation proposed by researcher in the world. For Indonesia case, the development model is very importance since there is a limited literature that discuss the construction and demolition estimation in since every state, region, cities and place have a unique pattern in infrastructure development. Moreover, it is also very difficult to find any information about characteristics of construction and demolition waste management in Indonesia. Construction waste management is important to avoid the negative impacts on the environment, social and economy [11, 12].

The study is very importance to run because information concerning data, method, model of construction and demolition waste management in Indonesia very limited. Study from Wu et al in 2014 shown that there is no information about construction and demolition waste management in Indonesia [13].

2. Regional Model of Smart Construction Waste Monitoring: A Part of Smart Infrastructure System Development in Regional Level.

To running the effective and efficient construction and demolition waste, availability model for estimation is very importance and significant [14]. Yost and Halstead, introduced basic methods to estimate construction and demolition waste for year 1996, in USA [14]. Kofoworola and Gheewala developed model for Thailand case in 2009 [16]. Wu et al in 2014 analysis literature that estimation for construction and demolition waste can be divided by four components [13]. First concerning to location at which country point. Second is waste generation activity at which associated to construction new building, demolition old building and other construction work and infrastructure development. Third refers to estimation level such as project level or regional level. Fourth is methodology such as generation rate calculation, lifetime analysis, classification accumulation and variable modeling [13].

Today smart system infrastructure development and implementation to making more convenience in service delivery to the citizen has been increasing worldwide. El Diraby 2001-2003 proposed definition of Smart Infrastructure System (SIS), at a system of utility and services that can monitor
itself and then adaptive and making automatic respond with environment change [17]. In line with the
definition and goal of infrastructure development goal to making and support rural urban live [2], then
it can be developed a concept of smart region infrastructure development as of the system of
infrastructure development that can conduct an automatic monitoring of environmental change in rural
urban at which automatically describe to program and project that should be develop to against
disaster and environment risk. In the context of Urban dan Regional Development in Indonesia, it is
in line with of Smart Region innovation for sustainable planning in regional level [18]. It means, smart
construction waste monitoring in regional level is part of smart regional infrastructure development.
Figure 1 describe the conception of smart construction waste monitoring and smart regional
infrastructure development. Refers to figure 1. The region has two city A, B and has two regency C,
D. City B is set as a central to monitor construction waste. Data of construction waste in City A, B and
Regency C, D is set can be seen automatically by using GIS approach or system information

\[ \text{Construction waste index of a regency / city in Central Java} = \frac{\sum I}{\sum Ni} \]

Where:
- \( I \) : Number of households in a district / city in Central Java
- \( Ni \) : Number of households in Central Java

Figure 1. Illustration concept of smart construction waste monitoring in region level

3. Data and Methods

3.1 Study area

This study selected Central Java Province as a region level of analysis. Central Java is one of
significant province in Indonesia at which consists of 35 Regencies and Cities. Central Java Province
is one Indonesia region that infrastructure development is run intensively since 90’s decade [19]. The
variable that considered to build a model is based on household or settlement data since it is one of the
principal infrastructure developed in Indonesia, not only for improving the physical environment [20],
but also for accelerating environmental health and human quality [21].

3.2 Method

Majority construction waste generation and characteristic arises from public housing [13,22]. To
analysis the monitoring system, a basic model developed base on household level. Proportion total for
construction waste distribution in Central Java is by 1 (one). then uses index approach to determine
the construction waste weigh and its distribution in Central Java. The calculation of construction waste
index is calculated from to total number of households in regency or city divided by total household of
Central Java. The following of the equation used to calculate the construction waste index to build the
model as of construction waste estimation compared to each other in Central Java:
The data used are the number of households in each Regencies and Cities for year 2000, 2005, 2010 and 2014 from the regional statistic data agency [23]. Moreover, this study utilized data from regional material store to understanding estimation distribution in Central Java Province. After calculating the construction waste index in each district and city in Central Java, this study exploring material store or material retail in Central Java. This method is used to developed basic spatial analysis concerning to the location and distribution construction waste base on consumption of material to develop settlement and housing, in GIS as of modified location analysis of retail by Benoit and Clarke [24], location of retail analysis by Reigadinha et all [25]. Regional model of smart construction waste for monitoring base on household and material store distribution in central java illustrated with GIS approach on 5 maps made for condition for year 2000, 2005, 2010 2014 and base on material store distribution in year 2019. In addition, three scale of the colour and its gradation introduced to describe the high level of construction waste distribution.

4. Result and Discussion

4.1 Settlement and Households Development in Central Java Province.

Central Java has 35 districts divided by 29 regency and 6 cities. For year 2000, Provincial Statistics Data administered 142,598 households in Rembang. The total number of households in Central Java in 2000 were 7,796,173 households. For year 2000 until 2005, the number of household development estimated increase 10.81 % become 8,639,208 households. While, in Rembang Regency, the development of housing estimated growth around 11.62% from year 2000 to 2005 become 161,350 households. In Central Java Province, for year 2010 there were 8,704,482 households and for year 2014 there were 009,084 households administered. Table 1 showed the data of settlement and household development in Central Java Province for year 2000, 2005, 2010 2014. The data is summarized from east zone to west zone of Central Java Province.

| No. | Regency         | Household and Settlement development recorded in Central Java Decade 2000, 2005, 2010, 2014 |
|-----|-----------------|----------------------------------------------------------------------------------|
| 1   | Rembang         |                                                                                   |
| 2   | Blora           |                                                                                   |
| 3   | Sragen          |                                                                                   |
| 4   | Kudus           |                                                                                   |
| 5   | Magelang        |                                                                                   |
| 6   | Banjarnegara    |                                                                                   |

| Year | Households | Index | Households | Index | Households | Index | Households | Index | Households | Index | Households | Index |
|------|------------|-------|------------|-------|------------|-------|------------|-------|------------|-------|------------|-------|
| 2000 | 142,598    | 0.0183| 161,350    | 0.0187| 162,602    | 0.0187| 168,851    | 0.0187| 172,067    | 0.0188| 175,389    | 0.0189|
| 2005 | 219,041    | 0.0181| 224,727    | 0.0181| 230,746    | 0.0187| 234,087    | 0.0187| 236,054    | 0.0188| 238,112    | 0.0188|
| 2010 | 222,600    | 0.0107| 226,608    | 0.0126| 215,054    | 0.0124| 224,326    | 0.0129| 225,992    | 0.0129| 235,891    | 0.0129|
| 2014 | 245,134    | 0.0037| 227,312    | 0.0031| 256,329    | 0.0029| 260,996    | 0.0029| 274,518    | 0.0029| 284,396    | 0.0029|

Table 1. Household development and Construction Waste Index Analysis for Central Java Province for year 2000, 2010 and 2014
4.2 Pattern of Construction Waste Generation Index (Increase or Decrease) as Representation of Infrastructure Development Growth in Central Java Province.

Construction waste is a material waste that arise from infrastructure development at which no value then be discharge to the environment by using final disposal for proper living and environmental safety. The volume of waste generated is a representation of the growth of infrastructure development [13,14]. The number of households in each district / city and the number of households in Central Java will determine the magnitude of the construction waste index. This section summarized the result of analysis by using excel program concerning to the data of household development index as represent of construction waste generation and infrastructure development in Central Java for decade 2000-2005; 2005-2010; 2010-2014. For the increase pattern as shown in figure 2, there are three pattern found for construction waste index as follow:

- **Pattern 1 (one) : Increase, Increase, Increase**
  Example for this pattern is founded in Pekalongan City, Rembang and Semarang Regency.

- **Pattern 2 (two) : Decrease, Increase, Increase**
  Example for this pattern is founded in Banyumas and Batang Regency.

- **Pattern 3 (Three) : Increase, Decrease, Increase**
  Example for this pattern founded in Sukoharjo and Karanganyar Regency.

Source: Household data [23], index data: analysis and calculation.

| No. | Regency       | Household and Settlement development recorded in Central Java Decade 2000, 2010, 2014 | 2000 | 2005 | 2010 | 2014 |
|-----|---------------|--------------------------------------------------------------------------------------|------|------|------|------|
|     |               | Households | Index | Households | Index | Households | Index | Households | Index | Households | Index |
| 27  | Pekalongan    | 179,623    | 0.0230 | 190,060    | 0.0220 | 195,561    | 0.0225 | 202,313    | 0.0225 |
| 28  | Pekalongan City | 60,896    | 0.0078 | 67,976    | 0.0079 | 69,872    | 0.0080 | 72,918    | 0.0081 |
| 29  | Pemalang      | 283,294    | 0.0363 | 352,595    | 0.0408 | 311,927    | 0.0358 | 317,586    | 0.0353 |
| 30  | Purbalingga   | 188,272    | 0.0241 | 222,640    | 0.0258 | 211,343    | 0.0243 | 221,366    | 0.0246 |
| 31  | Banyumas      | 371,832    | 0.0477 | 400,384    | 0.0463 | 420,273    | 0.0483 | 438,222    | 0.0486 |
| 32  | Tegal         | 319,311    | 0.0410 | 367,882    | 0.0426 | 355,107    | 0.0408 | 361,546    | 0.0401 |
| 33  | Tegal City    | 55,912     | 0.0072 | 61,710     | 0.0071 | 63,698     | 0.0073 | 65,133     | 0.0072 |
| 34  | Brebes        | 414,410    | 0.0532 | 460,648    | 0.0533 | 452,637    | 0.0520 | 462,950    | 0.0514 |
| 35  | Cilacap       | 401,629    | 0.0515 | 425,856    | 0.0493 | 443,794    | 0.0510 | 455,541    | 0.0506 |
|     | Total         | 7,796,173  |        | 8,639,208  |        | 8,704,482  |        | 9,009,084  |        |

Source: Household data [23], index data: analysis and calculation.
Totally this study founded seven pattern of construction waste generation in Central Java for Decade 2000-2014. Three increase pattern as shown in Figure 1. While for the decrease pattern describe in Figure 3 as follow:

- **Pattern 4 (Four)**: Increase, Increase, Decrease
  This pattern founded only in Banjarnegara Regency.
- **Pattern 5 (Five)**: Increase, Decrease, Decrease
  Example for this pattern founded in Blora, Sragen Regency.
- **Pattern 6 (Six)**: Decrease, Increase, Decrease
  Example for this pattern is founded in Boyolali and Cilacap Regency.
- **Pattern 7 (Seven)**: Decrease, Decrease, Decrease
  It mean in all decade waste construction index is decrease and decrease year by for decade 2000-2014 by decade. This condition is founded in Grobogan, Purworejo and Kebumen Regency.

**Figure 2. Pattern of Construction Waste Generation Index (Increase) for Decade 2000-2005; 2005-2010; 2010-2014**
4.3 Regional Model of Smart Construction Waste Monitoring : GIS approach for Household Base Framework in Central Java-Indonesia for year 2000, 2005, 2010 and 2014

Smart infrastructure system is a dynamic model of development process and the automatic monitoring since this model can monitor of the changing by them self [17]. GIS system is one of tools and approach that could be utilized to develop the model in regional level [17,18]. This section analysis a
basic model for regional for smart construction waste monitoring system based on line data for household development in province of Central Java-Indonesia [23]. This is the second step of development of smart construction waste for monitoring. GIS tools was utilized for model development. Model result for year 2000 as shown in figure 4, figure 5, Figure 6 and figure 7.

There were estimated 3 (three) gradation of the color from the map in figure 3, such as hard, Slightly Dark and Bright Color. It is represent a group and characteristic of waste construction waste generation based on spatial approach in Central Java for year 2000.

Table 2. Group of Gradation of Color from Regional Model of Smart Construction Waste Monitoring: Household Base Framework in Central Java-Indonesia for year 2000,2005,2010 and 2014

| Group Base on Gradation of color from the model | Region Code | Name of Region |
|-------------------------------------------------|-------------|----------------|
| I (Dark Color)                                  | 10,11,15,31,32,34,35 | Grobogan, Pati, Semarang City, Banyumas, Tegal, Brebes,Chilcap. |
| II (Slightly Dark Color)                        | 2,3,4,5,6,7,9,13,14, 16,18,21,25,26,27,29,30 | Blora, Sragen, Karanganyar, Wonogiri, Sukoharjo, Klaten, Boyolali, Jepara, Demak, Semarang, Magelang, Kendal, Kebumen, Banjarnegara, Pekalongan, Pemalang, Purwalingga. |
Refers to the table 1, concerning to the index value of construction waste generation, this section founded the classification of regional construction waste characteristic in Central Java as Follow:

- Region with high level of construction waste: Grobogan, Pati, Semarang City, Banyumas, Tegal, Brebes, Cilacap.
- Region with moderate/medium level of construction waste: Blora, Sragen, Karanganyar, Wonogiri, Sukoharjo, Klaten, Boyolali, Jepara, Demak, Semarang, Magelang, Kendal, Kebumen, Banjarnegara, Pekalongan, Pemalang, Purbalingga.
- Region with low level of construction waste: Rembang, Surakarta City, Kudus, Salatiga City, Magelang City, Temanggung, Batang, Pekalongan City, Tegal City.

### 4.4 Regional Model of Smart Construction Waste Monitoring: GIS approach for Material Store Base Framework in Central Java-Indonesia for year 2019

To making comparison with previous model in the section 2.3, this section utilized location approach of material store in Central Java as of location practical analysis and location theory by using GIS approach [24,25]. First step to develop the model is assessment of material store by online system. Table 3 summarized material store distribution by regency and cities in Central Java. Refers to the Table 3, the highest number of material store located in Semarang City, while the lowest number of material store located in Pekalongan City.

#### Table 3. Distribution of Material Store in Central Java 2019 (on line tracer)

| No. | Regency          | Number of Material for construction Store | No. | Regency          | Number of Material for construction Store |
|-----|------------------|-------------------------------------------|-----|------------------|-------------------------------------------|
| 1   | Rembang          | 128                                       | 19  | Magelang City    | 71                                        |
| 2   | Blora            | 188                                       | 20  | Temanggung       | 88                                        |
| 3   | Sragen           | 119                                       | 21  | Kendal           | 129                                       |
| 4   | Karanganyar      | 164                                       | 22  | Batang           | 53                                        |
| 5   | Wonogiri         | 143                                       | 23  | Wonosobo         | 126                                       |
| 6   | Sukoharjo        | 176                                       | 24  | Purworejo        | 63                                        |
| 7   | Klaten           | 189                                       | 25  | Kebumen          | 174                                       |
| 8   | Surakarta City   | 191                                       | 26  | Banjarnegara     | 253                                       |
| 9   | Boyolali         | 151                                       | 27  | Pekalongan       | 22                                        |
| 10  | Grobogan         | 166                                       | 28  | Pekalongan City  | 110                                       |
| 11  | Pati             | 110                                       | 29  | Pemalang         | 144                                       |
| 12  | Kudus            | 161                                       | 30  | Purbalingga      | 100                                       |
| 13  | Jepara           | 164                                       | 31  | Banyumas         | 186                                       |
| 14  | Demak            | 192                                       | 32  | Tegal            | 141                                       |
| 15  | Semarang City    | 223                                       | 33  | Tegal City       | 101                                       |
| 16  | Semarang         | 119                                       | 34  | Brebes           | 94                                        |
| 17  | Salatiga City    | 111                                       | 35  | Cilacap          | 193                                       |
| 18  | Magelang         | 96                                        | -   | -                | -                                         |

Source: Analysis and online assessment.
Model of material store with spatial approach by using GIS then develop. As shown in figure 8, the spatial distribution of construction waste base on material store distribution can be defined as follow:

- Region High level of construction waste was founded in region of Surakarta, Semarang and Tegal.
- Region Moderate level of construction waste was founded in region of Klaten, Kudus, Salatiga City, Magelang City, Wonosobo, Banjarnegara, Banyumas
- Region low level of construction waste was founded in region of Rembang, Blora, Sragen, Karanganyar, Wonogiri, Sukoharjo, Boyolali, Grobogan, Demak, Semarang, Magelang, Temanggung, Kendal, Wonosobo, Purworejo, Kebumen, Pekalongan, Pemalang, Purbalingga, Tegal, Brebes, Cilacap.

Figure 8. Basic model of construction waste based on total building store in Central Java 2019

5. Conclusion
Today, Construction waste monitoring is one of significant issue associated with the acceleration of Infrastructure development in Indonesia. In line with the era of revolution industry 4.0, and to ensure the construction waste management environmentally sound, this study introduce the basic model to estimate and monitor construction waste generation. By using Index and GIS tools this study developed spatial model of construction waste monitoring system. In addition by selected Central Java Province, this study developed Regional Model of Smart Construction Waste Monitoring. Result of analysis in this region then classified as three characteristic of Regional Model of Smart Construction Waste as follow:

- Region with high level of construction waste characteristic
- Region with moderate level of construction waste characteristic
- Region with low level of construction waste characteristic

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References

[1] Cheng J C and Ma L Y 2013 A BIM-based system for demolition and renovation waste estimation and planning Waste management 33(6): 1539-1551

[2] Grigg N S (1988) Infrastructure Engineering and Management Toronto: John Wiley & Son

[3] Brown C Milke M & Seville E 2011 Disaster waste management: A review article Waste management 31(6): 1085-1098

[4] Pemerintah Republik Indonesia 2008 Undang Undang No 18 Tahun 2008 tentang Pengelolaan Sampah Lembaran Negara RI tahun 2008 No 69 Sekretariat Negara Jakarta Dinas Desa Kesehatan tanggal 7 Agustus 2019

[5] Ying L Yin Z Guo T & Zhou J 2011 Analysis and research of management policy of construction waste in Beijing Procedia Environmental Sciences 11: 906-911

[6] AG Bossink and HJH Brouwers 1996 Construction waste: quantification and source evaluation Journal of Construction Engineering and Management ASCE 122(1): 55–60

[7] L L Ekanayake and G Ofori 2000 Construction material waste source evaluation Proceedings: Strategies for a Sustainable Built Environment Pretoria

[8] Tanikawa H Hashimoto S & Moriguchi Y 2002 Estimation of material stock in urban civil infrastructures and buildings for the prediction of waste generation Proceedings of the Fifth International Conference on Ecobalance Tsukuba Japan 68

[9] Katz A & Baum H 2011 A novel methodology to estimate the evolution of construction waste in construction sites Waste management 31(2) 353-358

[10] Masudi A F Che Hassan C R Mahmood N Z Mokhtar S N & Sulaiman N M 2012 Waste quantification models for estimation of construction and demolition waste generation: a review International Journal of Global Environmental Issues 12(2-4): 269-281

[11] Shen L Y Hao J L Tam V W Y and Hou H 2007 A checklist for assessing sustainable performance of construction project J. Civil Eng. Manage. 13(4): 273-28

[12] Nagapam S Rahman I A and Asmi A 2011 A Review of Construction Waste Cause Factors Asian Conf on Real Estate: Sustainable Growth Managing Challenges (Terengganu) 11(2):101-104

[13] Wu Z Ann T W Shen L Y Hao J L Tam V W and Hou H 2007 Quantifying construction and demolition waste: An analytical review Waste Management 34(9): 1683-1692

[14] Tam V W 2008 On the effectiveness in implementing a waste-management-plan method in construction Waste Management 28(6): 1072-1080

[15] Yost P A & Halstead J M 1996 A methodology for quantifying the volume of construction waste Waste Management & Research 14(5): 453-461

[16] Kofoworola O F & Gheewala S H 2009 Estimation of construction waste generation and management in Thailand Waste Management 29(2): 731-738

[17] El-Diraby T E 2003 A Framework for Integrated Data Management in Smart Infrastructure Systems Construction Research Congress doi:101061/40671(2003)100

[18] Sutriadi R 2018 Defining smart city smart region smart village and technopolis as an innovative concept in Indonesia’s urban and regional development themes to reach sustainability IOP Conference Series: Earth and Environmental Science 202(1): 012047

[19] Sidabutar P Rukmana N van der Hoff R & Steinberg F 1991 Development of urban management capacities: training for integrated urban infrastructure development in Indonesia Cities 8(2): 142-150

[20] Aswicahyono H & Friawan D 2008 Infrastructure development in Indonesia International Development in East Asia–Towards Balanced Regional Development and Integration’Economic Research Institute for ASEAN and East Asia research project report Chiba Japan: IDEJETRO 131-165 retrieved from url : http://www.ertia.org/uploads/media/Research-Project-Report/RPR_FY2007_2_Chapter_5pdf

[21] Kusharjanto H & Kim D 2011 Infrastructure and human development: the case of Java Indonesia Journal of the Asia Pacific Economy 16(1): 111-124
[22] Poon C S Yu A T W Wong S W & Cheung E 2004 Management of construction waste in public housing projects in Hong Kong Construction Management & Economics 22(7): 675-689
[23] Central Java Provincial Statistics Agency Central Java in figure year 2000 2005 2010 and 2014 Retrieved from https://jatengbpsgoid/ July and August 2019
[24] Benoit D & Clarke G P 1997 Assessing GIS for retail location planning Journal of Retailing and Consumer Services 4(4): 239-258
[25] Reigadinha T Godinho P & Dias J 2017 Portuguese food retailers—Exploring three classic theories of retail location Journal of Retailing and Consumer Services 34: 102-116