Specification of Map Generalization from Large Scale to Small Scale Based on Existing Data

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Abstract. Nowadays, the up-to-date and consistent digital spatial information is highly expected by the users. The kind of mapping method development which offers the potential to meet the high expectations is automatic map generalization. In Indonesia map generalization was only implemented in medium and small scale, and has never been done from large scale. This research aims as a beginning in map generalization from large scale by looking at the condition of existing data at all three levels of scale. Therefore, the data selected must be available on large, medium, and small scale. In this study, Bogor is chosen because it had been mapped on a scale of 1:5,000; 1:25,000; and 1:250,000. These operations used are a) selection, b) classification, c) amalgamation, d) aggregation, and e) simplification. The feature studied in this research is building. From this research, we can determine generalization pattern from scale of 1:5,000 to scale of 1:25,000 and 1:250,000 for building feature, so it can be used as prototype design in building generalization from large scale to medium and small scale.

1. Introduction
Nowadays, the up-to-date and consistent digital spatial information is highly expected by the users [1]. Multi-scale database system is much more important than single-scale database system due to it makes the system run interactively. National Mapping Agency (NMA) as authorized institution of national base map of each country is now facing the challenge, i.e. speed and quality of base map production. Up-to-date and consistent spatial information are huge goals of each NMA. The lack of consistent and up-to-date base map (including fundamental datasets e.g. geodetic control, elevation, drainage, land cover, etc) are becoming the common problems of some countries in the world [2].

The kind of mapping method development which offers the potential to meet the high expectations is automatic map generalization [1]. Map generalization is the process to get smaller-scale maps from larger-scale maps [3]. Generalization produces the selected and simplified data so the complexity is reduced by the scale change consequences [4][5]. Map generalization has become a function for zooming and multi-scale modelling in GIS, which integrates multi-scale data for spatial planning especially supports on-demand mapping within web services [3][6][7][8][9]. Although generalization is a traditional topic in cartography, now it changes and being developed to the digital map generalization as a computerization impact in recent decades [3][10].

We know that it is difficult to locate the exact date on which research on digital map generalization started [3]. Li stated that there are three significant research on generalization that published in 1966 i.e. by Tobler in 1966, about numerical map generalization [11] (updated in 1989 due to significant changes [12]), research by Töpfer and Pillewitzer in 1966 that describe the principal of selection on generalization [13], and by Perkal 1966 who proposes an objective generalization concept at the first time [14]. However, the author found that the term of generalization has been mentioned in 1964 as
the part of general cartography on the paper entitle "Cartography as an University Discipline" which has been written by Maling [15].

Basic principle of generalization which is still applied is introduced by Grünreich in 1985 namely “the generalization is a sequence of modelling operations from real world to primary model (Digital Landscape Model), secondary model (Digital Landscape Model) and cartographic product (Digital Cartographic Model)”. The main idea of that concept i.e. “real world to DLM” is model generalization to produce digital data at the certain scale, then “DLM to DCM” is cartographic generalization to produces ready to print map [16]. Figure 1 depicts the Grünreich scheme.

![Generalization as a modelling operation](image)

Figure 1. Generalization as a modelling operation [16]

The example of DLM and DCM concept implementation has been briefly explained by Stoter [17][18]. By that example, Stoter used TOP10NL to TOP50NL generalization sample which was shown by Figure 2. Shea and McMaster published the paper about why, when and how to generalize [19]. One of the reasons in arguing the necessary of generalization as Stoter said is the integration of dataset at different map scales for the automation implementation of multi-scale database in order to get consistency of each scale. Many review papers about generalization research e.g. by Oosterom in 2009 who identified current state of the art and further research and development direction [20], by Li in 2007 who reviewed digital map generalization of the first forty years [3], by Stoter in 2005 who reviewed about the generalization within some NMAs in the 21st Century [21], by Foerster, Stoter, and Kraak in 2010 who did the qualitative and quantitative analysis to get generalization automation within European NMA [22], and by Brassel and Weibel in 1988 who did the automation of generalization and propose a conceptual framework of map generalization [23].

Li explained that generalization research has been started since 1966 [3]. After 1966, many other studies focused on generalization e.g. automation generalization for national mapping production needs. Examples of synthesis of generalization operations used in generalization research can be seen in Table 1 obtained from Su [24] which has been cited by Li [3]. Some specific studies on certain elements such as building generalization are carried out by Basaraner and Selcuk [25] and Ruas [26]. In addition, examples of research on conflict space both line and area in relation to generalization are carried out by Buttenfield, McMaster, and Freeman [27], Cheng and Li [28], Gao et al [29], and Selvi, Bildirici, and Yerci [30]. Then, research that seeks to bridge the gap between theory and practitioners in this case the production needs of the National Mapping Agency, among others, are
related to the automation and evaluation of generalization results that have been carried out by several researchers, namely Bard and Cedex [31], Chaudhry, Mackaness, and Regnauld [32], Daoud and Doytsher [33], Hardy [34], Zhou, Regnauld, and Roensdorf [35], Smith et al. [36], Mackaness, Perikleous, and Chaudhry [37], Revell, Regnauld, and Thom [38], Stoter [17], and Burghardt, et al. [9].

![Figure 2: TOP10NL as DLM (a) and TOP50vector as DLM (b) then TOP50map as implementation sample of DCM (c) [17]](image)

**Table 1. Operation of map generalization by Su [3]**

| Operation       | Steward (1974) | Robinson et al. (1984) | Delicia & Black (1987) | McMaster & Monmonier (1989) | Keates (1989) | Shea & McMaster (1989) | Beard & Mackaness (1991) | McMaster & Shea (1992) |
|-----------------|----------------|-----------------------|------------------------|-----------------------------|---------------|------------------------|------------------------|------------------------|
| Agglomeration   |                |                       |                        |                             |               |                        |                        |                        |
| Aggregation     |                |                       |                        |                             |               |                        |                        |                        |
| Amalgamation    |                |                       |                        |                             |               |                        |                        |                        |
| Classification  |                |                       |                        |                             |               |                        |                        |                        |
| Coarsen         |                |                       |                        |                             |               |                        |                        |                        |
| Collapse        |                |                       |                        |                             |               |                        |                        |                        |
| Combination     |                |                       |                        |                             |               |                        |                        |                        |
| Displacement    |                |                       |                        |                             |               |                        |                        |                        |
| Enhancement     |                |                       |                        |                             |               |                        |                        |                        |
| Exaggeration    |                |                       |                        |                             |               |                        |                        |                        |
| Induction       |                |                       |                        |                             |               |                        |                        |                        |
| Merge           |                |                       |                        |                             |               |                        |                        |                        |
| Omission        |                |                       |                        |                             |               |                        |                        |                        |
| Refinement      |                |                       |                        |                             |               |                        |                        |                        |
| Selection       |                |                       |                        |                             |               |                        |                        |                        |
| Simplification  |                |                       |                        |                             |               |                        |                        |                        |
| Smoothing       |                |                       |                        |                             |               |                        |                        |                        |
| Symbolisation   |                |                       |                        |                             |               |                        |                        |                        |
| Typification    |                |                       |                        |                             |               |                        |                        |                        |

Best practice of the implementation of generalization research results were described by Stoter [21]. Stoter provides examples of Belgium, Spain, Denmark, France, Germany, Great Britain, The Netherlands, Ireland, Sweden, and Switzerland. One country that has been successful in implementing generalizations since 2010 for production purposes is the United Kingdom with the Vector Map District of Ordnance Survey (OSUK). Every 6 months OSUK automatically generalizes to update the map at the district level (1:25,000) using a master map without interaction with humans. Another example is Kadaster, The Netherlands which has started object-oriented databases since 2007.
Initiation of feasibility of generalization automation began in 2010 with a generalization case scale of 1:10,000 (called TOP10NL) to 1:50,000 (TOP50NL) map [1].

In Indonesia map generalization was only implemented in medium and small scale, and has never been done from large scale. Topographic map in scale of 1:500,000 was created from scale of 1:250,000 and scale of 1:1,000,000 was created from scale of 1:500,000. In medium scale, map generalization was implemented in One Map Policy. One Map Policy requires topographic map used is in scale of 1:50,000, while most topographic maps are available on medium scale are on scale of 1:25,000. Therefore, map generalization has done to produce scale of 1:50,000 in all regions of Indonesia.

Method of map generalization applied to One Map Policy is based on research by Susetyo and Perdana [39], that is by determining parameters for selection, simplification, and aggregation. More complex research is still needed to implement that method from large scale to medium and small scale. This research aims as a beginning in map generalization from large scale by looking at the condition of existing data at all three levels of scale. Therefore, the data selected must be available on large, medium, and small scale. In this study, Bogor is chosen because it had been mapped on a scale of 1:5,000; 1:25,000; and 1:250,000.

The feature studied in this research is building. From this research, we can determine generalization pattern from scale of 1:5,000 to scale of 1:25,000 and 1:250,000 for building feature, so it can be used as prototype design in building generalization from large scale to medium and small scale. In the end, if developed further, this method is expected to be used to accelerate the availability of topographic maps on all scales consistently.

2. Method

Topographic Map of Indonesia at 1:5,000 scale (RBI5K) is used for the generalization input of this research. For generalization result comparison, RBI25K and RBI250K are used in this research. RBI is the product of Geospatial Information Agency (NMA’s of Indonesia). The location sample of this research is Bogor, West Java, Indonesia. Figure 3 shows the building data of RBI at different scales.

![Figure 3. Sample of RBI data](image)

The operations of building generalization which is used in this research referenced to Savino [40]. These operations are a) selection, b) classification, c) amalgamation, d) aggregation, and e) simplification. Selection will select the shape-describing, characteristic, point to retain or will reject the redundant point considered to be unnecessary to display [40]. Simplification produces a reduction in number of derived data [19]. Then classification is concerned with the grouping of objects into certain categories [19]. Through amalgamation of individual building into a larger element, it is possible to retain the general characteristics of a region despite the scale reduction [41] on [19]. The aim of aggregation process is to reduce the density of objects [19]. The illustrations of classification, amalgamation, aggregation and simplification are depicted in Figure 4.
3. Result and Discussion

3.1. Selection of buildings

Selection of buildings is carried out depending on the geometry. If the area is more than 0.5 mm x 0.5 mm at scale of 1:25,000 (it means 12.5 m x 12.5 m in the real world), the source buildings must be retained. On the contrary, if it is below the threshold, the building is selected. There are two options in making a building selection: conversion to point and elimination.

School building is one of the objects that is converted into point. Because of its importance, school area is retained as point in scale of 1:25,000, while the surrounding area is grouped into settlement. Figure 5 shows the example, when SMP Negeri 1 Megamendung at scale of 1:25,000 still depicted, but as point shape. This also applies to the other public buildings, such as police offices, government offices, army headquarters, worship places, or health facilities.

![Figure 5. Comparison of school area at each scale](image)

The other buildings, such as business centre, industry, sport facility, entertainment area, or orphanage are eliminated if the area is less than 12.5 m x 12.5 m. For example, Cisarua market is still displayed as building area because of its large buildings whose area is more than the threshold (Figure 6). If the area is smaller than minimum requirement, it should be deleted, such as Jungleland in Figure 7.

![Figure 6. Comparison of business centre at each scale](image)
According to Savino [40], the specifications state that only buildings that have an area size smaller than a threshold value (in his research, the minimum building size is 50 square meters) should be deleted, and this should be done only if the building was not isolated. To detect the isolation of the buildings, the 500 meters buffer was set around each small building and finds whether any other building is inside this buffer. This parameter can be applied for map generalization in Indonesia, so isolated building can be retained. However, if the isolated building is less than the threshold, then it must be converted to point.

3.2. Classification / Grouped into settlement
Housing complex is recommended to be grouped into settlement. The buildings that are grouped into settlement are houses inside the housing complex, while if there is a public building in the area (such as mosque inside housing complex), then the process is the same as described in point 3.1. Figure 8 shows one of housing complex in Bogor, where at scale of 1:5,000 each building was digitized, and at scale of 1:25,000 it is depicted as settlement with its surrounded area.

3.3. Amalgamation and aggregation
The purpose of the amalgamation is all the buildings that are adjacent should be merged together, while the process of aggregation is used to merge together two buildings that are not adjacent [40]. Figure 9 and 10 show amalgamation and aggregation process, respectively.
In this research, a good sample to apply amalgamation is an industrial complex. There are some large buildings that stick each other, and in scale of 1:25,000 it is merged as a single building (Figure 11). When its building in scale of 1:5,000 is amalgamated, the result is not much different with existing 1:25,000 data. Figure 12 shows that difference. The distance parameter used here is 1 meter, it means if the distance between polygon boundaries satisfies 1 meter or below, the buildings will be aggregated.

Meanwhile, a good sample to apply aggregation is in shophouses. In existing 1:5,000 data, each building in the shophouses is digitized. Figure 13 shows it at each scale. If aggregation was applied in the data by merging all buildings with the edge is the outermost side of buildings, the result is displayed in Figure 14. The distance parameter used in that data is 50 meters.
Figure 13. Comparison of shophouses at each scale

Figure 14. Comparison between existing 1:25,000 data and from aggregation process with distance parameter used is 50 meters

However, if the parameter used must be consistent, the result will be different. From the first time, the parameter used is 0.5 mm on the scale of 1:25,000 or 12.5 meters in the real world. Therefore, the aggregation distance should be 12.5 meters. If aggregation distance is 12.5 meters, the result is shown at Figure 15.

Figure 15. Comparison between existing 1:25,000 data and from aggregation process with distance parameter is 12.5 meters

3.4. Simplification

The simplification strategy from Savino [40], relied on two algorithms: one to reduce the number of points in each geometry, the other to remove the small details from the facades. The method used in this research is remove the small details or elimination of juts (Figure 16). The algorithm is an iterative procedure that removes from a building all the facades that are shorter than a threshold; the decision of how to remove a short facade depends on the geometry of the neighbouring sides [40]. The minimum side chosen by Savino [40] is 3 meters.
This simplification is also implemented in generalization at medium scale, and Figure 17 shows the example of building simplification at medium scale. If it is applied in generalization from 1:5,000 to 1:25,000, the threshold is 0.5 mm or 12.5 meters in real world. It is different with parameter chosen by Savino [40] at output scale.

Simplification can be applied both in single building and building from amalgamation or aggregation. The sample used here is a single building, i.e. a bank. The bank still displayed as an area at scale of 1:25,000 as shown in Figure 18. The difference between existing data from scale of 1:25,000 and from simplification process is shown in Figure 19.
Building at scale of 1:25,000 from existing data
Buildings from simplification process

**Figure 19.** Comparison between existing 1:25,000 data and from simplification process

### 3.5. Recommendation for specification of map generalization

First step in map generalization from scale of 1:5,000 to 1:25,000 is selection of buildings. The parameter used is minimum area, where if the area is more than 0.5 mm x 0.5 mm at scale of 1:25,000 (it means 12.5 m x 12.5 m in the real world), the source buildings must be retained. The selection process is carried out with two methods: elimination and conversion to point. It depends on building function, where public buildings such as government office, school, health facility, state security office, and worship building are converted to points if the area is not sufficient. Meanwhile, buildings that are more private such as business centre, industry, sport facility, entertainment area, and orphanage are eliminated if the area is below the threshold. Housing complex is recommended to be grouped into settlement. The buildings that are grouped into settlement are houses, whereas if there is a public building in the area (such as mosque inside housing complex), then the process is the same as described before. Shortly, selection for each building feature can describe in Table 2.

Exceptions are given to isolated building. To detect the isolation of the buildings, the 500 meters buffer was set around each small building and finds whether any other building is inside this buffer. Isolated building must be retained, however, if the isolated building is less than the minimum area requirement, then it must be converted to point.

| Feature                | 1:25,000                                      | 1:250,000                                      |
|------------------------|-----------------------------------------------|-----------------------------------------------|
| Government office      | Depend on building area, can be **converted to point** if the area is not sufficient | Grouped into settlement                       |
| Education (school)     |                                               |                                               |
| Health facility        |                                               |                                               |
| State security office  |                                               |                                               |
| Worship building       |                                               |                                               |
| Business centre        |                                               |                                               |
| Industry               |                                               |                                               |
| Sport facility         | Depend on building area, can be **eliminated** if the area is not sufficient |                                               |
| Entertainment area     |                                               |                                               |
| Orphanage              |                                               |                                               |
| Housing complex        | **Grouped into settlement**                   |                                               |

Then, amalgamation and aggregation process can be processed to merge adjacent buildings. It can be applied in a building complex which is not a settlement, such as industrial complex or business.
centre. Amalgamation can be applied to merge buildings that are very close or sharing boundary, and our recommendation is to use 1 meter as distance parameter. Then, for aggregation, even though the result in Figure 14 (with distance parameter of 50 meters) is more similar with existing data, our recommendation is to use 12.5 meters as distance parameter to merge the buildings. It is because 0.5 mm has been specified as minimum requirement almost in every parameter in this research, so by choose 12.5 meters as parameter number, it will be more consistent.

The last is simplification. Simplification is applied both in single building, amalgamated/aggregated building, and settlement area. The threshold is minimum length of each side, where 12.5 meters is redefined as a parameter number.

Then, to generalize to scale of 1:250,000, all of buildings are grouped into settlement, except very important buildings. Based on existing data, only head of government’s offices that still appear on scale of 1:250,000, with the lowest administration that still displayed is sub-district level. So, all buildings are grouped into settlement, exclude offices of President, Governor, Regent/Mayor, and Sub-district Head.

Shortly, generalization process from 1:5,000 to 1:25,000 and 1:250,000 can be described in Figure 20.

Figure 20. Generalization process for building feature
4. Conclusion

Nowadays, the up-to-date and consistent digital spatial information is highly expected by the users [1]. The kind of mapping method development which offers the potential to meet the high expectations is automatic map generalization [1]. Map generalization is the process to get smaller-scale maps from larger-scale maps [3]. Generalization produces the selected and simplified data so the complexity is reduced by the scale change consequences [4][5].

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