Sturdy and modular concept of 2 in 1 public furniture design by recycling massive plastic waste

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Abstract. A large amount of plastic waste in Indonesia has not been properly managed. From this phenomenon a solution is needed, namely creating a product made from plastic waste to reduce the massive amount of available plastic waste. The product that is potentially high to be developed and can make use of large amounts of plastic waste is public furniture. Considering the use of public furniture will be managed by the local government, the condition of the waste recycled products will be easier to preserve. To develop the plastic waste-based public furniture, a few procedures were carried out, such as observations to city parks, conducting interviews with the local government and with a plastic recycling company, studying the plastic physical properties, conducting experiments on the plastic waste treatment, benchmarking furniture that utilizes plastic waste, and analyzing park visitor activity. From the obtained data, an analysis of material selection was carried out based on the fulcrum strength and resistance to crack and weather. After that, the exploration of forms was carried out with the criteria of modular, sturdy, multi-configuration, and unity. The result of this study is the design of 2 in 1 public furniture (park bench and planter) which consists of 3 modules that can be arranged according to needs. One set of modules weighs 17 kgs.

1. Introduction
The amount of waste human throws away is rising by the increasing level of public consumption and other activities. Among the types of waste, the most dominant is the type of plastic waste. Indonesia is the second biggest plastic waste producer in the world with a total amount approximately 1.29 million metric tonnes. [1]. Research from Sustainable Waste Indonesia (SWI) revealed that as much as 24 percent of waste in Indonesia are still not managed [2]. This means, of the approximately 65 million tons of waste produced in Indonesia every day, around 15 million tons pollute the ecosystem and the environment because they are not thoroughly handled. Meanwhile, 7 percent of waste is recycled, and 69 percent of waste end up at the final disposal site.

According to Halliwell and Lambert [3], plastics are classified into 2 types, namely: thermoplastic and thermosetting. Thermoplastic is a type of plastic that is commonly applied as packaging materials with LDPE, PP and ACETATE varieties. The characteristics of thermoplastic can be easily reformed and to be processed into other forms, lightweight, energy efficient and affordable. Utilization of plastic waste can be done with reusing and recycling plastic. In Indonesia, the utilization of plastic waste on a household scale is generally by reusing it for different needs, for example, a used plastic paint container reutilized as pots or buckets. The negative side of reuse, especially in the form of packaging is often used for counterfeiting products as it is common in big cities [4].
Plastics have several advantages such as corrosion-resistant, durable, good insulator, inexpensive, and easy fabrication. Plastic can be printed (or reprinted) into many desired shapes. In general, there are some requirements so that plastic waste can be processed by an industry, among others are waste must be in a certain form as needed (seeds, pellets, powder, fractions), waste must be homogeneous, not contaminated, and as much as possible not to be oxidized. To overcome this, plastic waste is processed before it is used through simple steps, namely separation, cutting, washing, and removal of substances such as iron and so on [5].

The advantage of utilizing plastic waste in Indonesia compared to developed countries is that it is possible to separate it manually. Manual separation is difficult to be implemented in developed countries due to the significantly higher labor cost. It is possible in Indonesia because there is an abundant workforce so that separation does not need to be done with sophisticated equipment that requires high costs. This condition allows for the development of the plastics recycling industry in Indonesia [6].

Next, the type of products that can potentially absorb large amounts of plastic waste must be elaborated for the effectiveness of the recycling process. The examples of those products are public furniture, such as benches and planters. Also, these products can meet the needs of Ruang Terbuka Hijau (RTH) or green open space of the city. The benefits of plastic waste are not only enabling the sustainability and recycling practice, but they also help as an education for students. One example of plastic waste implementation as a media is a research done by Siarni, Marungkil pasaribu, dan Amran rede, with a title Implementation of Used Goods As A Learning Media to Upgrade The Science Learning Result of Students In Grade IV, Government Elementary School 07 North Salule Mamuju was that this research showed an increase in the learning results of the students [7]. Besides to support teachers to choose an exciting and encourage the students to study, the students were more creative. Furthermore, Their products of creativity was able to be sold or use it for their own good.

2. Research Methods

Data search was performed to obtain the Design Requirements and Objectives (DR&O) for bench and planter products. First, observations were made at "Robries", a small plastic waste processing industry in Surabaya-Indonesia which is also the research partner of this study. The observation was taken to identify the processing steps in recycling plastic and the limitations. This observation was followed by a study about plastic processing, along with various kinds of plastic processing equipment. Besides this, a comparative study of furniture products using plastic waste materials was carried out. Furthermore, the selection of plastic types is decided based on the study of the physical properties of several types of plastic: High-Density Polyethylene (HDPE), Low-Density PolyethyleneLPDE, and Poly Propylene (PP).

Analysis carried out in this research includes public furniture analysis, what is the problem and needs; analysis of plastic waste material to be recycled into benches and planters; dimension analysis, to determine the dimensions of public furniture based on human factor and anthropometric standards and observations; joining analysis to select the most efficient connection system based on predetermined criteria; and then configuration analysis, to find out how the product can be configured.

3. Results and Discussions

3.1 Public Furniture Analysis

Public furniture data that have been obtained by observations in five city parks in Surabaya, is the basis in identifying the problems and analyzing the needs. The following Tables 1 and 2 present the identified problems and needs for city park benches and planters.
Table 1. Problems and needs found in city park benches

| Problems | Needs |
|----------|-------|
| There are cracked or damaged parts in many benches made of cast cement material | Park benches should be sturdy and durable, made of strong materials arranged in a good structure |
| Benches with iron material will be less comfortable to sit on after being exposed to hot weather. | Park benches should use a combination of materials that are resistant enough to weather to make it more comfortable. |
| Benches design ignores the objects or surrounding elements. | Design benches should consider the surrounding objects so there will be harmony. |

Table 2. Problems and needs found in city park planters

| Problems | Needs |
|----------|-------|
| Large planters have edge sizes more than 20 cm, that is commonly misused as seats. Therefore, the planter is easily damaged and later it may damage the plant as well. | The planter should have the form that human cannot sit on it, so it can save the plants. |
| The planter made of cast cement did not have a good water circulation, and the structure is not strong enough, so it is easily cracked and damaged. | Planter with sturdy material and structure, and has good water circulation, so it is more durable. |
| There is no unity of shape for each planter used in the park. | Planter design should have unity in form. It may be arranged together or separately but still look aesthetically pleasing. |

3.2 Dimension Analysis

3.2.1 Planters

Planters in Surabaya city parks are very diverse in shape and size according to the available space and the needs of each park. The decision of planter dimensions is based on observations that were conducted. The widely used shape and size or capacity of the planter are considered. A variety of planter sizes in the form of pots with a minimum of 2 different sizes are needed to meet the needs of a plant varieties plants. Figure 1 in the following shows pictures of some shapes and sizes of planters found in the parks, as well as the recommended standard sizes for structuring plants in city parks.

Figure 1. Common sizes of Surabaya city park planters in length × width × height (in centimeters)
Based on observations that were conducted in several Surabaya city parks (Taman Flora, Taman Bungkul, Taman Harmoni, and Taman Persahabatan), it is suggested that the circle and rectangle shapes of the existing planter must be changed into hexagonal or 6 facets to enable a more diverse configuration. Moreover, two size variations will be available, namely 40×40cm and 80×80cm. The number of uses of these two size variations are dominant and can already accommodate a diverse of plant sizes ranging from small to large, compared to other sizes, as depicted in Figure 2.

**Figure 2.** Former basic shapes of the city park planter are circle and rectangular. Those shapes are transformed into a hexagon (with six facets)

### 3.2.2 Bench

To determine the bench dimension, identification of the needs has been made based on studies of existing benches in four Surabaya city parks. The point is, not only that the shape is designed to meet aesthetic needs but is also functional. Analysis was carried out to determine the basic shape of the bench, whether it is using a long bench design, a long bench with a divider, or a short bench (single seat). The criteria comprise of product’s ability to accommodate park visitors' sitting activities, comfortable to sit on for a duration of 1-30 minutes, product’s ability to prevent being used for sleeping, accommodate personal space between bench users. Based on those criteria, some design alternatives of benches have been generated by considering human anthropometry as shown in Figure 3.

**Figure 3.** Bench design alternatives for city parks

Based on the criteria explained in the previous paragraph, the most suitable bench design is then determined. The short bench (single seat) is the selected design. This design is not only had an advantage of not being used for sleeping but also can provide a comfortable personal space for users or visitors of city parks, with a more flexible arrangement.
3.3 Analysis of Plastic Waste Material

The main ingredient in the manufacture of products that will be formed by molding is Plastic that has been processed into plastic ores [8]. The steps in the plastic waste processing into the main material of the product can be described as follows:

- The type of HDPE plastic was selected because HDPE has the best tensile strength [9] compared to PP and LDPE plastic. The plastic waste was obtained from a waste bank that has been classified according to the type and color of the plastic. After that, it was then chopped or shredded, as exhibited in Figure 4, by using a grinding machine.
- Chopped plastics were then filled into a 41 × 31 cm mold with a thickness of 2 cm. The mold shaped the plastic when the chopped plastics are melted. The use of metal for the mold material is due to the fact that it is durable and is a good conductor of heat.

![Figure 4. Chopped plastic is poured on a board](image)

- Plastic molds, as exemplified in Figure 5, were put into the oven for the plastic melting process. The plastic melted at temperatures of 160-240º C (LDPE), 200-280º C (HDPE), and 200-300ºC (PP). During the melting process, 2× pieces of plastic were added because the plastic shrunk continuously.
- The chopped plastics that had been melted, were then removed from the oven and pressed into the mold. The press was held in place until the temperature decreases. When the mold was already cold, the plastic was able to be removed from the mold. The form of plastic waste will be the same as the mold form.

![Figure 5. Mold is being pressed](image)

- Next, the 41 × 31 cm plastic board is divided into smaller sections. The cutting process used the table saw. This process was followed by leveling the surface into 1.5 cm using planner, as the height of the board still varies.
• The process of leveling the surface of the plastic parts used a planner machine because the results from the mold were not evenly distributed 2 cm on the surface area. Thus, All parts were levelled to 1.5 cm. Figure 6 illustrates the process at this stage.

![Figure 6. Planner was used to leveling the board into 1.5 cm](image)

• The following steps were joining boards. The boards were glued together using epoxy glue with a 1:1 mixture ratio between the resin and the hardener. It was then coated, then waited for up to 30 minutes. Iron clamps must be used for pressing plastic boards, as shown in Figure 7. Then it is left to dry for 24 hours.

![Figure 7. Process of pressing plastic using clamps](image)

• Next, the planter and benches needed holes for handling and joining. The holes were processed using Computerized Numeric Control (CNC) machine, as seen in Figure 8.

![Figure 8. Hole making on plastic board using CNC](image)

• All parts that are ready, glued together into one module using epoxy glue following a negative mold made of plywood, held using a rope and a screw to strengthen the bond. Then leave it to dry for 24 hours.
• To close the former screw and patch the connection that was not neat, more chopped plastics were used by melting them using a heat gun. The process of finishing each plastic part was by using a sandpaper machine or sander with sandpaper number of 120, 400, up to 800.
• Dowels for the joining system were made from 3D printed plastic. A technology using a special printing machine to create a formerly designed object that was then printed into a real 3D object created [10]. The results of the 3D printed object had supports for the build and had rough edges and surfaces, which was then sanded to cleaned them up.
• Lastly, modules of waste plastic processing were ready to be assembled into a bench set or planter. Figure 9 presents the finished planter module.

![Figure 9. Planter module made of plastic waste was ready](image)

3.4 Joining Analysis
Joining was needed to ensure that the benches and planter products met the design criteria, namely modular, interchangeable, and stackable. The joining system for each module has the criteria, of which include ease of installation or assembly, strong connection, simple and neat connection and not easily removed by the user.

The types of connections that made it possible to combine modules in a stacking system are joineries, dowels, and threads using bolts and nuts, as exhibited in Figures 10 to 12. The locking system was adapted from the connection system that used wood.

![Figure 10. 1st alternative joint design](image)
By the consideration of connection criteria above, the 3rd alternative joint design is selected, namely dowel. A locking system using a plastic dowel was applied to combine modules into a stacking system.

3.5 Configuration Analysis
The product adapted a stacking or stacking system to combine modules into a set of finished products. There are 3 modules to make 1 set of benches, and 2 modules for the planter. With a modular system applied to the product, it will simplify the assembly process. The assembly can be done before the product was delivered to the Robries workshop, or anywhere the product will be located, like in a city park. The following Figures 13 and 14 are examples of the configuration of merging modules into a set of public furniture.
4. Conclusions
Plastic waste can be recycled into a product that has value and function. Broadly speaking, the process of molding plastic waste is started from counting the plastic material, melting the material, then pressing into a desired mold, cooling, and finally finishing. The greater the product that is produced, the more plastic waste is used. The results of this study are 2 in 1 public furniture designs (park benches and planters) consisting of 3 modules is found to be capable to be arranged into a variety of configurations according to the desired needs. One set of modules weighs 17 kg which is equivalent to 17,000 plastic water bottle cap wastes. A similar research was done by two students form Petra University, Sheilly Yuliani Purnomo and Andereas Pandu Setiawan. These two students, utilized plastic waste they found in the sea and recreated the waste into wall decorations and a top table. They used a stove, fire and an oven for the melting process and molded it inside a triangle and a rectangle-shaped metal mold [11]. It is hoped that this research will not only provide information on how to process plastic waste into finished products, but also give an idea that plastic waste can be processed into products of higher value and have the opportunity to be explored further so that the absorption of plastic waste is more intensified.

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References
[1] Sofiana,Y. (2010). “Pemanfatan limbah plastik sebagai alternatif bahan pelapis (upholstery) pada produk interior”. J. of Humaniora Binus 11(2):96-102.
[2] Dini, T. (2018). 24 Persen Sampah di Indonesia Masih Tak Terkelola. Kementerian Dalam Negeri Republik Indonesia, retrieved from: http://litbang.kemendagri.go.id/website/riset-24-persen-sampah-di-indonesia-masih-tak-terkelola.
[3] Halliwell, J. and Lambert, B. (2004). Graphics with Materials Technology. Heinemann Educational Publishers, Oxford, England.
[4] Suyadi. (2010). “Kaji eksperimen kekuatan tarik produk-produk berbahan plastik daur ulang”. Proc. of Seminar Nasional Sains dan Teknologi, Semarang, Jawa Tengah, Indonesia, Jun. 15 pp. 104-111.
[5] Syahfitrie. (2001). Analisis Aspek Sosial Ekonomi Pemanfaatan Limbah Plastik. Institut Pertanian Bogor, Bogor, Indonesia.

[6] Purnomo, S.Y. and Setiawan, A.P. (2019). Eksperimen Material Sampah Laut Sebagai Material Pendukung Ruang Interior. Universitas Kristen Petra, Surabaya, Indonesia.

[7] Ahvenainen, R. (2003). Modern Plastics Handbook. Woodhead Publishing, Cambridge, UK.

[8] Herliati, Prasetyo, S.B. and Verinaldy, Y. (2019). “Potensi limbah plastik dan biomassa sebagai sumber energi terbarukan dengan proses pirolisis”. J. Tekno. FTI Universitas Jayabaya 6(2):85-98.

[9] Larasati (2014). Mengenal Lebih Dekat Teknologi 3D Printing. International Design School Education, retrieved from: https://idseducation.com/articles/mengenal-lebih-dekat-teknologi-3d-printing.

[10] Tapkire, G., Parihar, S., Patil, P. and Kumavat, R.H. (2014). “Recycling plastik used in concretepaver block”. J. of Research in Eng. and Techno. 3(9):33-35.

[11] Siarni, M.P. and Rede, A. (2017). Pemanfaatan Barang Bekas sebagai Media Pembelajaran untuk Meningkatkan Hasil Belajar IPA Siswa Kelas IV SDN 07 Salule Mamuju Utara. Universitas Tadulako, Palu, Indonesia.