This initiative is supported by **PacWastePlus**-a 72 month project funded by the European Union (**EU**) and implemented by the Secretariat of the Pacific Regional Environment Programme (**SPREP**) **to sustainably and cost effectively improve regional management of waste and pollution.**

Palau End-of-Life Tire Technical Booklet for Landscape Beautification

January 2025

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Our vision: A resilient Pacific environment sustaining our livelihoods and natural heritage in harmony with our cultures.

PacWaste Plus Programme

The Pacific – European Union (EU) Waste Management Programme, PacWaste Plus, is a 72-month programme funded by the EU and implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP) to improve regional management of waste and pollution sustainably and cost-effectively.

About PacWaste Plus

The impact of waste and pollution is taking its toll on the health of communities, degrading natural ecosystems, threatening food security, impeding resilience to climate change, and adversely impacting social and economic development of countries in the region.

The PacWaste Plus programme is generating improved economic, social, health, and environmental benefits by enhancing existing activities and building capacity and sustainability into waste management practices for all participating countries.

Countries participating in the PacWaste Plus programme are: *Cook Islands, Democratic Republic of Timor-Leste, Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, Republic of Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu*.

Key Objectives

Outcomes & Key Result Areas

The overall objective of PacWastePlus is "*to generate improved economic, social, health and environmental benefits arising from stronger regional economic integration and the sustainable management of natural resources and the environment*".

The specific objective is "*to ensure the safe and sustainable management of waste with due regard for the conservation of biodiversity, health and wellbeing of Pacific Island communities and climate change mitigation and adaptation requirements*".

Key Result Areas

- **Improved** data collection, information sharing, and education awareness
- **Policy & Regulation** - Policies and regulatory frameworks developed and implemented.
- **Best Practices** - Enhanced private sector engagement and infrastructure development implemented
- **Human Capacity** - Enhanced human capacity

Learn more about the PacWaste Plus programme by visiting

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Glossary

Terminology	Definition
De-beading	Removing the metal bead from the rim of the tire, required for some downstream processing of ELTs to reduce wear on shredder blades.
End-of-life Tires (ELT)	A tire that is deemed no longer capable of performing the function for which it was originally made.
Granules (Granulated rubber)	A refined rubber product typically between 2-15mm in diameter, made from recycled tires.
Shredding	Process of cutting up waste tires using bladed shafts in an enclosed vessel, the size of product being determined by number and orientation of blades and/or number of passes (output screening)
SPREP	Secretariat of the Pacific Regional Environment Programme, the Client for this report.
Tire	A vulcanised rubber product designed to be fitted to a wheel for use on, or already fitted to, motorised vehicles and non-motorised trailers towed behind motorised vehicles.
De-beading	Removing the metal bead from the rim of the tire, required for some downstream processing of ELTs to reduce wear on shredder blades.
End-of-life Tires (ELT)	A tire that is deemed no longer capable of performing the function for which it was originally made.

1. Introduction

This booklet is designed to provide practical, step-by-step guidance to Landscaping companies on reusing End-of-Life Tires (ELTs) in three specific applications:

- Playground Structures,
- Outdoor Furniture and,
- Synthetic Playground Surfaces and Athletic Tracks.

The purpose of this booklet is to outline the requirements for utilising ELTs in these applications, ensuring compliance with relevant engineering standards and industry best practices. The guidance includes:

- Pre-Treatment Requirements: Basic steps needed to select and prepare ELTs for use.
- Processing Requirements: Detailed instructions for processing pre-treated ELTs for specific applications.
- Engineering Standards: Relevant standards to ensure safety, durability, and environmental compliance.
- Cost Considerations: Estimated capital and operational costs.
- Monitoring Requirements: Guidelines for ongoing inspection and maintenance.

ELTs are a versatile material with significant potential for use in landscaping projects. This booklet provides clear and concise guidance to help landscaping teams implement these solutions effectively. Designed with hands-on professionals in mind, the information is presented in a straightforward manner, using simple language and practical examples to ensure accessibility and ease of on-site application.

2. Playground Structures

2.1 Method of Utilisation

ELTs offer a cost effective and sustainable opportunity to create unique and interesting playground structures. Simple playground structures can be constructed by cutting, painting and conjoining ELTs to create for example:

Mazes: constructed by stacking ELTs in a vertical wall formation which is no higher than 2m to ensure children's safety (possible fall from climbing). Tires of similar sizes should be selected and their sidewalls removed. They should be positioned in a maze formation and then filled with a soil, rock and/or sand mixture with good compressive qualities. The mixture should be distributed and then pound using a sledgehammer to effectively compress the mixture into the sidewalls. Once the sides are adequately filled, the centre area of the tire should receive more mixture that is again compressed. The next row of ELTs is then laid on top in a staggered/overlapping pattern. The fill and compression steps are repeated. Continue until wall reaches its full height (up to 2m).

Climbing play equipment: constructed with ELTs stacked in pyramid (or other) shapes, example shown in Figure 1 left. It is recommended that structures should be no greater than 2m high and involve gradient slopes no greater than 45° from the horizontal to ensure children's safety (possible fall from climbing). ELTs should be fastened together effectively using bolts (ensuring bolts do not stick out too far in areas where children may reach to avoid injury).

Tire swings: constructed with whole tires, rope or chain in a simple swing frame structure example shown in Figure 1 right. A sturdy simple swing frame can be constructed with wooden/metal beams/poles. Drill holes 1-2cm in tire for chain connection. This can be done either in two-four even spaces along the ring rim of the tire for a horizontal tire swing or in one spot along the sidewall of the tire for a vertical tire swing. Ensure chains and carabiners or bolt links are securely fastened and are rated for at least 200kgs. Additional chains can be added for further security as shown in Figure 1 right.

Playground structure ladders: can be constructed with ELTs by bolting tires to wood planks, example shown in Figure 2. It is recommended that structures should be no greater than 2m high and involve gradient slopes no greater than 45° from the horizontal to ensure children's safety (possible fall from climbing). ELTs should be fastened together effectively using bolts (ensuring bolts do not stick out too far in areas where children may reach to avoid injury).

Half Tire balance beams/stools: Can be constructed by halving ELTs; first the sidewall should be removed and then tires can be halved (processing requirements outlined in following sections). Using halved tires, secure them to the playground flooring using brackets and bolts to create balance beams, stools and or tunnels, examples shown in Figure 3. Alternatively, if the playground surface is soil or sand, disregard tire halving steps and simply bury half of the ELT in an upright position beneath the surface, ensuring sand or soil is reinforced with binding/compressive mixture which is pounded using a sledgehammer to effectively secure the tire in place for play activities (Figure 3).

***Note**: For any of the above applications, painting ELTs for aesthetic and stylistic reasons is possible; to ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if*

Figure 1: Playground equipment using tires *(Garcia 2021; Playsound 2023).*

Figure 2: Playground Ladder made from tires *(Exploring Domesticity 2013).*

Figure 3: Playground balance beams/stools with ELTs

2.2 Pre-Treatment Requirements

It is suggested that ELTs be treated according to the steps outlined in Figure 4 and below before they can enter the processing stage and be used.

ELTs used as playground structures should meet all pre-treatment requirements including:

- Be whole, intact tires.
- No exposed Steel Wires exposed
- Not have been exposed to fire or extreme temperatures; ensure there are no visible signs or smells of smoke, burned rubber or deformation from heat.

ELTs that do not meet the above requirements should be rejected and disposed at the Tire Recycling Facility at M Dock.

- ELTs should be inspected before processing and meet all grade requirements.
- ELTs deemed unnacceptable should be rejected.
- ELTs deemed acceptable should be sorted by size, condition, and type.
- ELTs should be cleaned before their re-use, resulting in a higher quality end product. Cleaning should be performed in a hardstand area and using a powerwasher. Ensure all contaminants and organic material are removed. Ensure runoff water is treated and free from contamination before discharging.

Figure 4: Pre-processing Steps for ELT whole Tire use

2.3 Processing Requirements

The following Processing requirements for ELTs as playground structures are required.

For mazes:

Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

If painting the maze is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.
- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

For climbing play equipment:

- It is recommended that drainage holes be drilled in whole ELTs which are used in beautification projects to ensure drainage and mitigate water collecting as this could lead to mosquito infestation. Drill 1-5 holes in the bottom of the tire using a 10-20mm diameter drill. Ensure standard tool safety handling procedures are followed including the proper securement of the object, the use of PPE, exclusion zones and maintenance of tools.
- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

If painting the climbing play equipment is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.

- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

For tire swings:

- It is recommended that drainage holes be drilled in whole ELTs which are used in beautification projects to ensure drainage and mitigate water collecting as this could lead to mosquito infestation. Drill 1-5 holes in the bottom of the tire using a 10-20mm diameter drill. Ensure standard tool safety handling procedures are followed including the proper securement of the object, the use of PPE, exclusion zones and maintenance of tools.
- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

If painting the tire swings is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.
- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

For playground structure ladders:

- It is recommended that drainage holes be drilled in whole ELTs which are used in beautification projects to ensure drainage and mitigate water collecting as this could lead to mosquito infestation. Drill 1-5 holes in the bottom of the tire using a 10-20mm diameter drill. Ensure standard tool safety handling procedures are followed including the proper securement of the object, the use of PPE, exclusion zones and maintenance of tools.
- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

If painting the playground structure ladders is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.
- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

For half tire balancing beams/stools:

- Removing ELT side walls: use a tire Sidewall Cutter (machine) or manually using a utility knife or retractable box cutter. Ensuring cutter has a metal safe blade.
- ELT halving: use a power saw or manual saw. Ensure tool has a metal-safe blade. Lay the tire flat on its side on a clear and safe workspace, using a power saw or manual saw, press the cutting edge into the tire across the sidewall- slowly move the tool from the inner edge to the outer edge. Turn the tire over and complete the cut from the opposite side.
- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

If painting the half tire balancing beams is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.
- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

2.4 Applicable Engineering Standards

There is no applicable engineering standards required for the use of whole ELTs for playground structures.

It is essential to adhere to recognised general and safe handling methods throughout the process. To ensure safety and quality:

For mazes:

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

For climbing play equipment:

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

For tire swings:

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

For playground structure ladders:

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

For half tire balancing beams/stools:

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

2.5 Capital Cost

For mazes:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1,200)
- ELT processing requires:
  - **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)

For climbing play equipment:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1,200)
- ELT processing requires:
  - **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)

For tire swings:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1,200)
- ELT processing requires:
  - **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)

For playground structure ladders:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1,200)
- ELT processing requires:
  - **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)

For half tire balancing beams/stools:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1,200)
- ELT processing requires:
  - **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)

- **Tire sidewall cutter** (machine) – approx. US$1,000, or **utility knives** – approx. US$20 per knife.
- **Power saw or manual saw** – approx. US$10-60

2.6 Operational Cost

- **Labour** – 3-5 persons- standard, unskilled workers: Palau minimum wage US$4.25 per hour
- **Administration** – visual monitoring one person- skilled supervisor: Palau minimum wage US$4.25 per hour
- **Utilities** – water & electricity: cost varies project dependant.
- **Miscellaneous** – exterior acrylic paint & primer: approx. US$30-50 per litre.
- **Consumables** – fire safety equipment & PPE: approx. US$180 per worker, per year.
- **By-Products Disposal** – nil: unused tires should be returned to the stockpile. Sump waste – oil, grease and grit must be disposed of to landfill: zero fees, excess water can be discharged.

2.7 Monitoring Requirements

The following monitoring requirements are recommended during the pre-treatment and processing stages of ELTs as playground structures.

- Pre-treatment: minimal monitoring is required during the pre-treatment stages; however, regular quality control checks are to be conducted by a suitably experienced professional to ensure project standards are met. If deemed unfit, ELT should be rejected and disposed at the tire Recycling Facility at M Dock.
- Processing: periodic checks by a professional are required during processing to verify quality and ensure efficacy of the final product.

3 Outdoor Furniture

3.1 Method of Utilisation

ELTs offer a cost effective and sustainable opportunity to create unique and interesting pieces of outdoor furniture. Simple pieces of furniture can be constructed by cutting, painting and conjoining ELTs to create chairs, tables, footstools, barriers along walkways and pet beds or even flooring such as stair coverings and non-slip surfaces.

Boarders/barriers: Figure 5 depicts ELTs used as boarders/barriers along pathways constructed by simply burying half of the ELT in an upright position beneath the surface, ensuring sand or soil is reinforced with binding/ compressive mixture which is pounded using a sledgehammer to effectively secure the tire in place.

Outdoor chairs and tables: Figure 6 & Figure 7 showcase an outdoor chair and table arrangement made from ELTs in Timor-Leste, chairs and tables like these could be constructed by stacking and bolting two tires together and adding either a soft foam or woven fabric to the middle tire hole to create a seat or a hard surface such as a wooden plank to the middle tire hole for a table. To half/quarter or other cutting techniques for ELTs; first the sidewall should be removed and then tires can be cut as desired (processing requirements outlined in following sections).

***Note**: If desirable, painting ELTs for aesthetic and stylistic reasons is possible; to ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).*

Figure 5: Tires used as boarders of paths (Creative Star Learning 2022).

Figure 6: Outdoor furniture along the beach front in Dili, Timor-Leste (Devine 2023)

Figure 7: ELT chairs and tables examples

3.2 Pre-Treatment Requirements

It is suggested that ELTs be treated according to the steps outlined in Figure 8 and below before they can enter the processing stage and be used.

ELTs used as outdoor furniture should meet all pre-treatment requirements including:

- Be whole, intact tires.
- Contain no potential hazards embedded in or amongst the ELT such as exposed steel wires etc.
- Not have been exposed to fire or extreme temperatures; ensure there are no visible signs or smells of smoke, burned rubber or deformation from heat.

ELTs that do not meet the above requirements should be rejected and disposed at the Tire Recycling Facility at M dock.

- ELTs should be inspected before processing and meet all grade requirements.
- ELTs deemed unacceptable should be rejected.
- ELTs deemed acceptable should be sorted by size, condition, and type.
- ELTs should be cleaned before their re-use, resulting in a higher quality end product.
- Cleaning should be performed in a hardstand area and using a powerwasher. Ensure all contaminants and organic material are removed.
- Ensure runoff water is treated and free from contamination before discharging.

Figure 8: Pre-processing Steps for ELT whole Tire use

3.3 Processing Requirements

The following Processing requirements for ELTs used as outdoor furniture are required.

For boarders/barriers

- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

If painting the boarders/barriers is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.
- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

For outdoor chairs and tables

- It is recommended that drainage holes be drilled in whole ELTs to ensure adequate drainage and mitigate water collecting as this could lead to mosquito infestation. Drill 1-5 holes in the bottom of the tire using a 1-2cm diameter drill. Ensure standard tool safety handling procedures are followed including the proper securement of the object, the use of PPE, exclusion zones and maintenance of tools.
- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

When halving/quartering or cutting tires the following processing requirements are recommended:

- Removing ELT side walls: use a Tire Sidewall Cutter (machine) or manually using a utility knife or retractable box cutter. Ensuring cutter has a metal safe blade.

- ELT halving: use a power saw or manual saw. Ensure tool has a metal-safe blade. Lay the tire flat on its side on a clear and safe workspace, using a power saw or manual saw, press the cutting edge into the tire across the sidewall- slowly move the tool from the inner edge to the outer edge. Turn the tire over and complete the cut from the opposite side.

If painting the outdoor chairs and tables is desired, the following processing requirements are recommended:

- Ensure painting is completed in a ventilated area.
- Ensure paint safety instructions as per paint labels are followed e.g. avoid contact with skin and eyes.
- To ensure durability of paint for rubber application and outdoor use, first, coat the tire in an exterior primer, once dry, coat with an acrylic exterior paint (multiple coats if necessary).

3.4 Applicable Engineering Standards

There is no applicable engineering standards required for the use of whole ELTs for outdoor furniture.

It is essential to adhere to recognised general and safe handling methods throughout the process. To ensure safety and quality:

For boarders/barriers

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

For outdoor chairs and tables:

- Follow common industry practices e.g. wash hands after handling ELTs
- Use appropriate tools and equipment e.g. as recommended by manufacturers
- Ensure proper protective equipment (PPE) is used.

3.5 Capital Cost

For boarders/barriers:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1200)
- ELT processing requires:
  - **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)

For outdoor chairs and tables:

- ELT pre-processing requires:
  - **Tire washing facility** (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1200)
- ELT processing requires:

- **Miscellaneous** – Power drill, drill bits: approx. US$50-300 per drill (cost varies brand and quality dependant)
- **Tire sidewall cutter** (machine) – approx. US$1000, or **utility knives** – approx. US$20 per knife.
- **Power saw or manual saw** – approx. US$10-60

3.6 Operational Cost

- **Labour** – 3-5 persons- standard, unskilled workers: Palau minimum wage US$4.25 per hour
- **Administration** – visual monitoring one person- skilled supervisor: Palau minimum wage US$4.25 per hour
- **Utilities** – water & electricity: cost varies project dependant.
- **Miscellaneous** – exterior acrylic paint & primer: approx. US$30-50 per litre.
- **Consumables** – fire safety equipment & PPE: approx. US$180 per worker, per year.
- **By-Products Disposal** – nil: unused tires should be returned to the stockpile. Sump waste – oil, grease and grit must be disposed of to landfill: zero fees, excess water can be discharged.

3.7 Monitoring Requirements

The following monitoring requirements are recommended during the pre-treatment and processing stages of ELTs for outdoor furniture.

- Pre-treatment: minimal monitoring is required during the pre-treatment stages; however, regular quality control checks are to be conducted by a suitably experienced professional to ensure project standards are met. If deemed unfit, ELT should be rejected and disposed at the Tire Recycling Facility at M Dock.
- Processing: periodic checks by a professional are required during processing to verify quality and ensure efficacy of the final product.

4 Synthetic Playground Surfaces and Athletic Tracks

4.1 Method of Utilisation

Synthetic Playground Surfaces and Athletic Tracks can be made from granulated rubber derived from ELTs. ELT granulated rubber playground surfaces and athletic tracks are porous for increased usability and reduced water pooling and have high impact absorption which is ideal for outdoor play and running surfaces.

To construct synthetic playground surfaces and athletic tracks, ELTs should be granulated to 1-4mm in size. The granules are then mixed with a polymeric binder e.g. resin in a 18-20% resin to rubber granule ratio. The mixed rubber and resin compound can then be poured or laid using a trowel onto an existing concrete or crushed rock base (Figure 9). As represented in Figure 10, it is recommended that the base rock or concrete layer be a minimum of 100mm thick and the rubber compound layer be up a minimum of 50mm thick, however thicker rubber layers are recommended in play areas where children could fall from greater heights e.g. under a slide structure (resin bonded aggregates, n.d.). The rubber and resin compound takes approximately 60 minutes to set, during this drying time, wet surfaces should not be touched.

Figure 9: Installation of rubber and resin compound for playground flooring *(Liberty Floor Solutions 2024).*

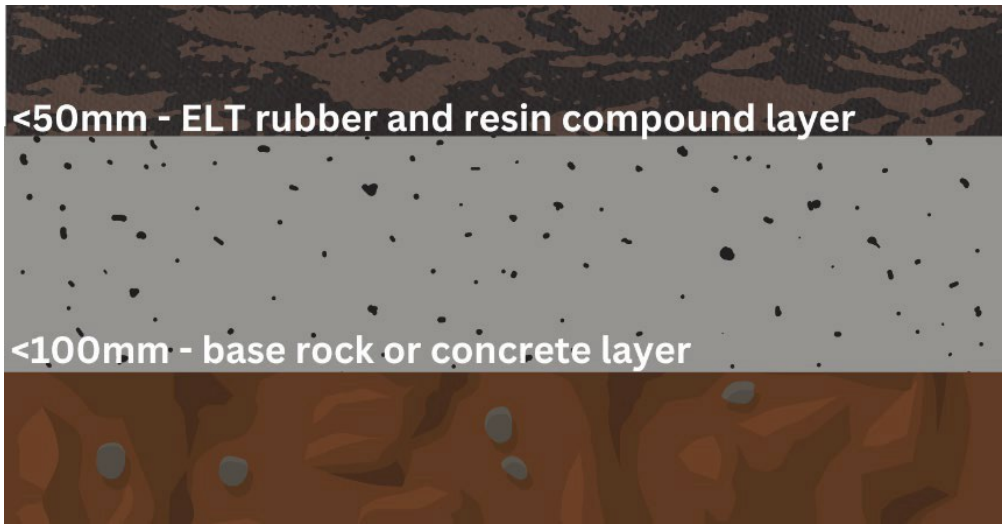

Figure 10: Synthetic Playground and Athletic Track Surface- cross section ground layer diagram

Figure 11 depicts an athletic track surfaced with *Technigom,* a material made from ELTs by Aliapur a French company (Communication Aliapur 2013). For more information and a video tutorial of *Technigom* installation visit: [Aliapur - Manufacture of an athletic track made with end-of-life Tires granulates :\ https://youtu.be/aadxho8AQOI?si=qxA3Ub7q2BvgHVDW](https://youtu.be/aadxho8AQOI?si=qxA3Ub7q2BvgHVDW)

Figure 11: Athletic track constructed from Tires *(Communication Aliapur 2013)*

4.2 Pre-treatment Requirements

It is suggested that ELTs be treated according to the steps outline in Figure 12 and below before they can enter the processing stage and be shred or crumbed.

ELTs used in synthetic playground and athletic track surfaces should meet all pre-treatment requirements including:

- Not have been exposed to fire or extreme temperatures; ensure there are no visible signs or smells of smoke, burned rubber or deformation from heat.

ELTs that do not meet the above requirements should be rejected and disposed at the Tire Recycling Facility at M Dock.

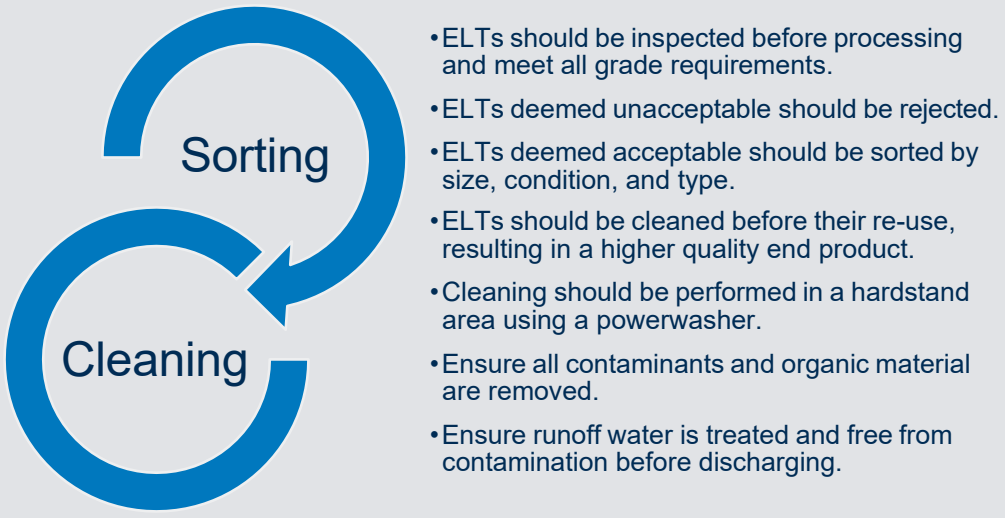

Figure 12: Pre-processing Steps for ELT granulation

4.3 Processing Requirements

The following processing requirements for ELTs used in synthetic playgrounds and athletic track surfaces are required.

- Tires are flammable. Tires should be stored in a stable condition in cool, dry, ventilated areas away from open flames and heat sources. It is recommended that firefighting equipment always be on hand when handling and processing tires.

***Note**: it is understood that currently in Palau processing of ELT involved shredding prior to debanding and debeading- the following steps have accounted for this process specification.*

Processing ELTs into shreds or crumbs involves a mechanical process as described below and in Figure 13.

1. **Cutting:** Cutting tires into smaller pieces may assist the shredding process. Cutting can be executed using a power saw, Dremel tool, strip cutter or block cutter, provide that they have a metal-safe blade.
2. **Shredding:** A shredder, such as a rotary shredder, is first used to reduce the waste tires to smaller pieces generally less than 150mm in size.
3. A wire drawing machine is an optional piece of equipment that may be used prior to shredding to draw the tire wires out of the tire to protect the blades of the shredder.
4. **Debanding and Debeading:** Tires that are reinforced by steel bands or beads should have these removed prior to being shredded or crumbed. Removal is done using a debanding and debeading machine.
5. **Contamination removal:** steel, nylon and fibre contaminants are removed from the shredded tires via a drum magnet and air separation (blower).
6. After passing through the shredder or a series of shredders and removal of the steel, the <150mm output can be processed into rubber granules or crumb.
7. **Size reduction:** a secondary shredder, also known as a grater or rasping machine, may be used for further size reduction (10-44mm) to create “rubber mulch”.
8. **Granulation:** the shredded rubber is put through a granulator to form rubber granules (2-15mm).

***Note:** Recommended final output granulated rubber should be between 1 and 4mm in size*

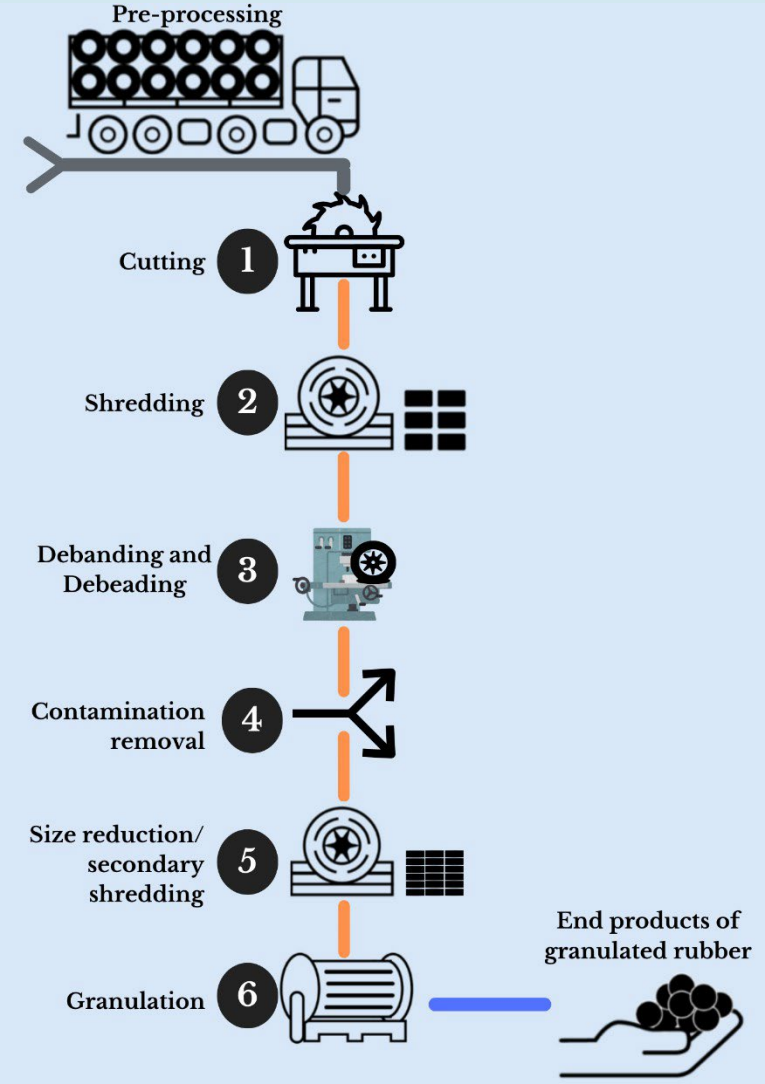

Figure 13: Tire shredding and granulation process

4.4 Engineering Standards

The use of ELTs in the production of synthetic playground surfaces and athletic tracks should be performed in accordance with specifications to ensure quality standards are achieved. The American Society for Testing and Materials (ASTM) develops and publishes technical standards which outline the necessary procedures for the classification and testing of materials.

***Note**: All engineering standards mentioned can be purchased from: ASTM International - Standards Worldwide*

The relevant standard for this project is:

- ASTM D6114/D6114M-19 Standard Specification for Asphalt-Rubber Binder.

To summarise, the relevant material specifications for ELT crumbed rubber before it is combined with resin for use as synthetic playground surfaces and athletic tracks include:

- Ground recycled tire rubber is to conform to requirements of:

- D1566-21a Standard Terminology Relating to Rubber: This standard outline technical terms used in the rubber industry, their definitions and expert recognition. The standard should be used if mathematical expressions are required for the time and temperature dependent physical properties of terms found within the Standard Specification for Asphalt- Rubber Binder
- D6373 Standard Classification for Rubber Compounding Materials-Recycled Vulcanizate Rubber: This standard classification outlines the compounding material of particulate rubber.

- Ground recycled tire rubber must contain less than 0.75% moisture by weight and shall be free flowing.
- Ferrous metal particles should not be visible and no more than 0.01% ferrous metal particles (by weight) are allowed in the final product.
- Fiber content cannot exceed 0.5% (by weight) of ground recycled rubber.
- No rubber particles can be retained in the 2.36mm sieve (maximum particle size).

To ensure these relevant testing and sampling procedures and material specifications are met, a laboratory must be identified and employed to provide quality control.

4.5 Capital Cost

For Synthetic playground surfaces and athletic tracks, ELT pre-processing requires:

- **Tire washing facility** – (Hardstand area: approx. US$18-38 per m^2, Pressure washer: approx. US$150, Sump tank: approx. US$1,200)
- **DeBeader** – between US$2,000 for small-scale debeaders to US$39,000 for large-scale debeaders

ELT processing requires:

- **Shredder** – between US$20,000-US$50,000 for small-scale shredders to US$100,000 for advanced shredders with additional features
- **Secondary Shredder** – US$300,000 to $600,000.
- **Crumbing Rubber Plant** – Granulators US $420,000 to US$600,000.

Example: Australian ELT facility for size comparison

A facility capable of processing **3,500 tonnes p/a of tires** with an output of crumb rubber and rubber granules.

Facility cap cost: **AUS$4,000,000** for main facility + **AUS$1,500,000** for pre-processing facility.

This would be considered a large-scale ELT recycling plant.

Engineering standards:

- ASTM D6114/D6114M-19 Standard Specification for Asphalt-Rubber Binder – US$61
- D1566-21a Standard Terminology Relating to Rubber – US$76
- D6373 Standard Classification for Rubber Compounding Materials-Recycled Vulcanizate Rubber – US$69

4.6 Operational Cost

Total operational costs are comprised of the following demands.

- **Labour** – labour intensive process, minimum 10-15 Full-time equivalent dependant on scale of project: Palau minimum wage US$4.25 per hour
- **Administration** – visual monitoring 1-3 persons- skilled supervisor: Palau minimum wage US$4.25 per hour
- **Contractors** – Laboratory contracted professionals for testing; regular testing required as per engineering standards: cost varies contractor dependant.
- **Utilities** – water, electricity & compressed air: cost varies project dependant.

- **Consumables** – processing equipment consumables including grinding surfaces, greases, lubricants, belts, spares etc: approx. US$250/tonne of processed ELTs. Fire safety equipment & PPE: approx. US$180 per worker, per year.
- **By-Products Disposal** –Sump waste – oil, grease and grit must be disposed of to landfill: zero fees, nylon textile disposal to landfill: zero fees, excess water can be discharged.

4.7 Monitoring Requirements

The following monitoring requirements are recommended during the pre-treatment and processing stages of ELTs for synthetic playground and athletic track surfaces.

- Pre-treatment: minimal monitoring is required during the pre-treatment stages; however, regular quality control checks are to be conducted by a suitably experienced professional to ensure project standards are met. If deemed unfit, ELT should be rejected and disposed at the Tire Recycling Facility at M Dock.
- Processing: Regular lab testing is required as per applicable engineering standards for Asphalt-Rubber Binder specification. Periodic checks by a professional are recommended during processing to verify quality and ensure efficacy of the final product.

5 References

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