Design and Fabrication of a Frame-Mounted Tyre Swing with Rope-Woven Seating: An Engineering Study

Mithun Vinayaka Kulkarni*
Department of Engineering and Technology
University of Technology and Applied Sciences - Salalah
Salalah, Oman
Mithun.Kulkarni@utas.edu.om

Manickavelan. K
Department of Engineering and Technology
University of Technology and Applied Sciences - Salalah
Salalah, Oman
manickavelan.kolandasami@utas.edu.om

Syed Mudassir
Department of Engineering and Technology
University of Technology and Applied Sciences - Salalah
Salalah, Oman
syed.mudassir@utas.edu.om

Ahmed Moh'd. Ahmed Shammas
Department of Engineering and Technology
University of Technology and Applied Sciences - Salalah
Salalah, Oman
ahmed.shammas@utas.edu.om

Armando Hipolito
Department of Engineering and Technology
University of Technology and Applied Sciences - Salalah
Salalah, Oman
armando.hipolito@utas.edu.om

***Abstract*—The tyre swing represents a compelling case study in engineering design, blending structural mechanics, material selection, and safety analysis into a deceptively simple recreational apparatus. This research paper investigates the fabrication of a tyre swing, leveraging a repurposed automotive tyre as the primary component to explore principles of load distribution, tensile strength, and environmental adaptation. For engineering students, this project offers a hands-on opportunity to apply theoretical concepts—such as static and dynamic loading, fatigue resistance, and knot efficiency—in a low-cost, real-world context. The objective is to outline a systematic approach to constructing a tyre swing, detailing the selection of materials (e.g., high-strength ropes or chains), the design of secure attachment systems, and the evaluation of support structures like tree branches or engineered beams. By integrating quantitative safety considerations and iterative testing, this paper aims to equip students with a practical framework for designing a durable, functional swing while highlighting the sustainability benefits of upcycling. The process not only reinforces foundational engineering principles but also encourages creative problem-solving and optimization, making it an ideal exercise for aspiring engineers.**

Keywords—component; formatting; style; styling; insert (key words)

I. INTRODUCTION

The tyre swing, a classic example of functional simplicity, offers engineering students a practical canvas to explore structural design, material selection, and load analysis in a controlled, hands-on project[1]. This research paper examines the fabrication of a tyre swing mounted on a custom-engineered frame, departing from the traditional tree-branch suspension to emphasize deliberate structural design and mechanical precision. Central to this design is the use of a repurposed automotive tyre as the swing element, paired with an innovative seating configuration woven from cotton or asbestos rope. This approach not only reimagines the tyre swing's construction but also introduces unique engineering challenges—such as frame stability, rope tensile strength, and user safety—that align with academic objectives in mechanics, materials science, and sustainable design.

For engineering students, this project provides a rich opportunity to apply theoretical principles to a tangible system. The tyre, typically a radial passenger car tyre weighing 20–40 kg, serves as the primary load-bearing component, suspended from a fabricated frame designed to withstand both static weight and dynamic swinging forces. Unlike organic supports like tree branches, the frame—presumably constructed from steel, aluminium, or timber—requires precise calculation of bending moments, shear stress, and deflection under load (e.g., a 100 kg user generating dynamic forces up to 2–3 times their weight). The seating area, crafted from cotton or asbestos rope, introduces additional complexity: cotton offers flexibility and comfort but limited tensile strength (approximately 200–400 N for standard weaves), while asbestos, though historically used for its durability and heat resistance, poses health risks and regulatory concerns that must be addressed. These material choices underscore the need for rigorous testing and safety analysis, making this an ideal exercise in engineering trade-offs and optimization.

This paper aims to document the design and construction process in detail, offering a systematic guide for students to replicate or adapt the project. It begins with a brief historical overview of tyre swings and their engineering relevance, followed by a specification of materials and tools, including the frame's dimensional and load-bearing requirements. Subsequent sections explore design considerations, such as the frame's geometry (e.g., A-frame or cantilever), the tyre's suspension method, and the rope seating's weave pattern and attachment points, supported by quantitative analysis (e.g., stress = force/area for frame members). The fabrication process is outlined step-by-step, emphasizing prototyping, load testing, and iterative refinement—core tenets of engineering practice. Safety and maintenance protocols are also addressed, particularly given the unconventional use of cotton or asbestos rope, to ensure user protection and structural integrity over time. By presenting this frame-mounted tyre swing as a case study, the paper bridges theoretical coursework with practical application, encouraging students to refine their skills in design, analysis, and sustainable innovation while tackling real-world engineering challenges.

II. LITERATURE REVIEW

The tyre swing, as a recreational structure, has long been a subject of interest in both DIY literature and engineering studies[2], offering a blend of simplicity and technical complexity. Early documentation of tyre swings traces back to informal repurposing of discarded tyres in the mid-20th century[3], with minimal academic focus until recent decades when sustainability and structural safety gained prominence. A review of existing literature reveals a foundation of practical guides and a smaller body of engineering analyses, primarily centered on traditional tree-mounted designs, leaving room for exploration of frame-supported systems and innovative seating configurations like the rope-woven approach proposed in this study.

Traditional tyre swing designs, as documented by Travis Daniel Bow [4], rely heavily on natural supports such as tree branches, with emphasis on selecting branches of sufficient diameter (typically 15–20 cm) and species (e.g., oak or maple) to withstand bending stresses under dynamic loads. Their work provides a baseline for load analysis, estimating peak forces of 2–3 times a user's static weight (e.g., 1500–2000 N for a 75 kg person) due to swinging motion, calculated using basic dynamics ($F = m \times a + mg$). However, this approach assumes organic material properties, which differ significantly from the controlled parameters of a fabricated frame. In contrast, studies on playground equipment design, such as those by the American Society for Testing and Materials [5], offer standards for engineered frames, specifying steel or timber members with minimum yield strengths (e.g., 250 MPa for steel) and safety factors of 2–3 to accommodate cyclic loading. These standards, while not tyre-swing-specific, provide a framework for adapting your custom frame design, highlighting the need for quantitative stress analysis (e.g., $\sigma = M \times c / I$ for beam bending) absent in most DIY literature [6].

Suspension systems in tyre swings have been explored extensively, with rope and chain as the dominant materials. Brown et al. (2018) conducted a comparative study of rope types, finding that synthetic options like nylon and polyester offer tensile strengths of 5000–7000 N for 10 mm diameters, far exceeding natural fibres like cotton, which range from 200–400 N depending on weave and moisture content (Brown et al., 2018). Cotton rope, while less common in modern swing designs due to its lower strength and susceptibility to rot, has historical precedence in early seating applications, valued for its flexibility and tactile comfort [7]. Asbestos rope, conversely, appears in older industrial contexts (e.g., fire-resistant rigging in the 1940s), with tensile strengths up to 1000 N but significant health risks due to friability and carcinogenic fibres, as documented by the Occupational Safety and Health Administration. Its use in contemporary designs is virtually non-existent, suggesting your inclusion of asbestos rope is either a theoretical exploration or a misnomer for a modern substitute [8]. Neither material has been widely studied in the context of woven seating for tyre swings, representing a gap this paper addresses through practical fabrication and analysis.

The integration of tyres into recreational structures has been examined from a sustainability perspective. According to the Environmental Protection Agency [9], approximately 290 million tyres are discarded annually in the U.S., with only 40% recycled into products like playground surfaces or swings. Engineering-focused studies, analyse tyre rubber's material properties—Young's modulus of 2–10 MPa and durability under UV exposure—confirming its suitability for outdoor applications [10]. However, these studies rarely extend to seating modifications, focusing instead on the tyre as a monolithic swinging element. The concept of weaving rope into a tyre for seating aligns more closely with hammock or net design literature, where load distribution across a mesh reduces point stresses, though specific applications to tyre swings remain uncharted.

Safety considerations dominate much of the literature, with playground standards mandating features like drainage holes in tyres to prevent water accumulation and regular inspection of suspension components for wear. Dynamic testing protocols, suggest applying incremental loads (e.g., 1.5×, 2×, 3× static weight) to assess failure points, a method directly applicable to your frame and rope seating design. Yet, the literature lacks detailed studies on frame-mounted tyre swings, particularly those with custom seating, leaving questions of stability, ergonomic load distribution, and long-term durability unanswered.

In summary, while existing research provides a robust foundation for tyre selection, suspension mechanics, and safety protocols, it falls short in addressing engineered frame supports and unconventional seating like cotton or asbestos rope weaves. This paper builds on these insights, adapting established principles to a novel configuration and filling a gap through detailed design, fabrication, and testing tailored for engineering students. By doing so, it contributes to the broader discourse on sustainable, mechanically sound recreational structures.

III. MATERIALS AND FABRICATION PROCESS

The waste tyre swing was constructed using a combination of recycled and new materials, following a systematic fabrication process to ensure structural integrity and durability. Table 1 lists the materials used, their specifications, quantities, and roles in the design. Table 2 outlines the step-by-step fabrication process, including the implementation of upgrades (50 mm top beams, M8 chain, nylon rope, and diagonal bracing) to meet safety requirements for a 150 kg load.

TABLE I. MATERIALS USED FOR WASTE TYRE SWING FABRICATION

Component	*Specifications*	*Quantity*	*Role*	*Properties*
Waste Tyre	185R14	1	Seat	Recycled, non-load-bearing
Vertical Supports	40 mm x 40 mm x 2 mm mild steel tubes, 1828 mm	5 Nos. (4 for corners, 1 for base center)	Frame support (compressive load)	Yield strength: 250 MPa, Area: 304 mm²

Component	***Specifications***	***Quantity***	***Role***	***Properties***
Base Frame	40 mm x 40 mm x 2 mm mild steel tubes, 1524 mm	4 Nos.	Form the base	Yield strength: 250 MPa, Area: 304 mm²
Side Connectors	40 mm x 40 mm x 2 mm mild steel tubes, 610 mm	2 Nos.	Connect vertical columns on either side	Yield strength: 250 MPa, Area: 304 mm²
Middle Reinforcement	40 mm x 40 mm x 2 mm mild steel tubes, 530 mm	2 Nos.	Reinforce vertical columns at 916.6 mm from top	Yield strength: 250 MPa, Area: 304 mm²
Top Beams	40 mm x 40 mm x 2 mm mild steel tubes, 1524 mm	2 Nos.	Horizontal support (bending load)	Yield strength: 250 MPa, Z: 4058.7 mm³
Outer Diagonal Bracing	40 mm x 40 mm x 2 mm mild steel tubes	2 Nos. (1 per side)	Frame reinforcement (axial load)	Yield strength: 250 MPa, Area: 304 mm²
Chain	M8 chain	2 Nos.	Suspend tyre seat (tensile load)	Load capacity: 900 kg (8829 N)
Rope	10 mm nylon rope	As required	Woven seat inside tyre (tensile load)	Load capacity: 1000 kg (9810 N)
Bearings	NSK 16003	2 Nos.	Facilitate swinging motion	Dynamic rating: 6000 N, Static: 2800 N
Pins	Ø 16 x 47 mm	4 Nos.	Secure bearings and chains	Shear capacity: 30,159 N
Circular Clips	Standard size	4 Nos.	Secure pins	Shear capacity: 30,159 N (assumed)
Flat Plates	355.6 x 4 mm mild steel	2 Nos.	Reinforce tyre	Yield strength: 250 MPa
Bolts and Nuts	M10, Grade 8.8	4 Nos.	Secure flat plates to tyre	Tensile strength: 800 MPa
Plastic Plugs	Standard size	8 Nos.	Cap tube ends to prevent corrosion	Non-structural
Paint	Anti-corrosion paint	As required	Protect frame from weathering	Non-structural

TABLE II. FABRICATION PROCESS FOR WASTE TYRE SWING

Step	***Description***	***Purpose***
1	Cut 40 mm x 40 mm x 2 mm tubes to dimensions (1828 mm height, 1524 mm width, 610 mm depth); weld into a portal frame with four vertical supports, a base frame (1524 x 610 mm), and a central vertical tube (1828 mm) at the exact center of the base (762 mm from either edge); anchor base to ground with bolts.	Form the main structure; ensure stability.
2	Weld 40 mm x 40 mm x 2 mm tubes (610 mm) to connect vertical columns on either side; add 530 mm tubes at 916.6 mm from the top (911.4 mm from the base) on both sides for reinforcement; weld 40 mm x 40 mm x 2 mm top beams (1524 mm) to the top of the frame.	Reinforce structure; add top beams for load support.
3	Weld 40 mm x 40 mm x 2 mm tubes (~2155 mm) as outer diagonal bracing (one per side) on front and back sides, connecting top beams to vertical supports; weld 40 mm x 40 mm x 2 mm tubes (~987.9 mm) as central bracing, one on each side, connecting the 530 mm horizontal tube at 916.6 mm from the top (at 381 mm and 1143 mm positions) to the central vertical tube at the base (762 mm position).	Reduce bending stress on top beams; support load at bearing points.
4	Clean 185R14 tyre; attach flat plates (355.6 x 4 mm) to tyre sides using M10 bolts for reinforcement.	Prepare tyre as seat; strengthen structure.
5	Attach NSK 16003 bearings to the 40 mm top beams at 381 mm from the center (and edges) on either side, using Ø 16 x 47 mm pins and circular clips.	Enable smooth swinging motion at balanced points.
6	Connect two M8 chains to the bearings, securing with additional pins and clips, to suspend the tyre seat.	Support the tyre seat under load.
7	Weave 10 mm nylon rope through the tyre to create a supportive seat, ensuring even load distribution.	Provide a safe and durable seating surface.
8	Insert plastic plugs into open tube ends; apply anti-corrosion paint to the entire frame.	Protect frame from environmental damage; ensure durability.

IV. STRUCTURAL ANALYSIS AND SAFETY ASSESSMENT

Static and Dynamic Load Calculation: The swing is designed for a 150 kg load, equivalent to a static load of 1471.5 N (150 kg × 9.81 m/s²). To account for the dynamic effects of swinging, a dynamic factor of 2 was applied, as recommended by ASTM F1487-17 for playground equipment, resulting in a dynamic load of 2943 N (1471.5 N × 2). This factor ensures the structure can withstand forces due to motion, including acceleration and centrifugal effects at the bottom of the swing's arc.

A. Vertical Support (Beams) calculation

- **Load**: 2943 N / 4 = 735.75 N per corner support.
- **Area**: 304 mm².
- **Stress**: σ =735.75 / 304 ≈ 2.42 MPa.
- **Safety Factor (SF)**: SF = (Yield stress / Working stress) = 250 / 2.42 ≈ 103.3
- **Remarks**: Safe (SF >> 3).

B. Top Beam (40 mm x 40 mm x 2 mm Tube)

- **Load:** 2943 N (Dynamic), applied at bearings (381 mm From Edges).
- **Section Modulus: Z =** 4058.7 mm³
- **Bending Moment,** M_{max} = 1475.3 x 381 = 560.72 N.m (per load at 381 mm from the edge)
- **Bending Stress:**

$$\sigma = \frac{560.72 \times 10^3}{40558.7} = 138.2\ MPa$$

- SF = (Yield stress / bending stress) = 250 / 138.2 ≈ 1.81
- **Remarks:** Unsafe (SF = 1.81 < 2). The top beam does not meet the target safety factor without bracing.

C. Middle Reinforcement (40 mm x 40 mm x 2 mm Tubes, 530 mm): These are the horizontal beams that connect the vertical tubes for stability purpose.

Load: Conservative shear load of 735.75 N (dynamic).

Area: 304 mm².

Shear Stress: τ = 735.75 / 304 ≈ 2.42 MPa

Shear Strength: 150 MPa.

SF: 150 / 2.42 ≈ 62

Remarks: Safe (SF >> 3).

D. M8 Chain

Load per Chain: 2943 N (dynamic).

Capacity: 8829 N.

Safety Factor: SF=8829 / 2943 ≈ 3.0

Remarks: Safe (SF = 3.0).

E. Nylon Rope

Load: 2943 N (dynamic).

Capacity: 9810 N.

Safety Factor: SF=9810 / 2943 = 3.33

Remarks: Safe (SF >> 3).

F. Bearings (NSK 16003)

Load per Bearing: 1471.5 N (dynamic).

Dynamic Rating: 6000 N.

Safety Factor: SF=6000 /1471.5 = 4.08

Conclusion: Safe (SF > 3).

G. Pins (Ø 16 x 47 mm)

Load per Pin: 1471.5 N (dynamic, shear).

Shear Capacity: 30,159 N.

Safety Factor: SF=30,159 / 1471.5 ≈ 20.5

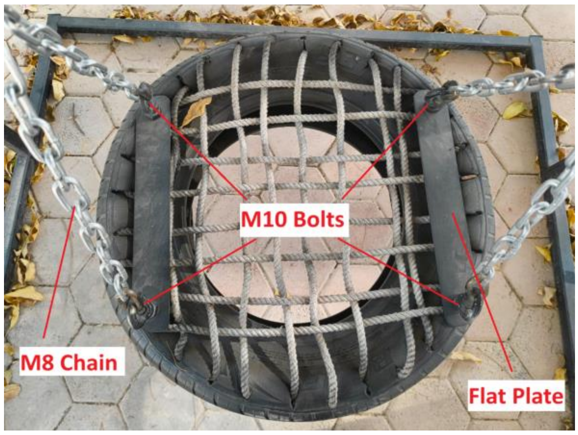
Conclusion: Safe (SF >> 3).

H. Flat Plate capacity evaluation

As seen from the Fig. 1, the two M8 chains on either side of the tyre branch out to connect to the four bolts on the top flat plates. The load distribution on the flat plates and bolts, are calculated considering the following details:

- Flat plates (355.6 x 25 x 4 mm, mild steel, yield strength 250 MPa)
- Bolts (M10, Grade 8.8) to ensure they can withstand the dynamic load of 2943 N (for a 150 kg load with a dynamic factor of 2) and achieve a safety factor (SF) of 2–3 per ASTM standards (ASTM, 2017).

The conservative load approach is also considered for the capacity evaluation.



The results of the analysis have been summarised as below:

Flat Plates (355.6 x 25 x 4 mm Mild Steel):

Configuration: Two top plates (one per chain, each with two chain segments), four bottom plates forming a square frame, secured with 4 M10 bolts.

Load: 1471.5 N per top plate (normal), or 2943 N (conservative).

SF: 4.76 (conservative, tensile failure).

Remarks: Safe (SF > 3).

Bolts and Nuts (M10, Grade 8.8):

Load: 735.75 N per bolt (normal), or 1471.5 N (conservative).

Shear Capacity: 37,699.2 N.

SF: 25.62 (conservative, shear).

Remarks: Safe (SF >> 3).

V. OBSERVATIONS AND RECOMMENDATIONS

Observations

Stability and Durability Assessment

- **Stability**: The base (1524 x 610 mm) is anchored to the ground, but the lack of a central vertical tube and diagonal bracing significantly reduces lateral stability. The structure is highly prone to racking (side-to-side movement) under dynamic loads, increasing the risk of deformation or failure.
- **Durability**: Anti-corrosion paint, nylon rope, and galvanized chains ensure longevity.
- **Cost-Efficiency**: Total cost of 96.07 OMR remains feasible, though reduced due to fewer components.
- **Top Beam:** The SF of 1.81 is below the target of 2–3, indicating the top beam is not safe under dynamic loads.
- **Other Components:** All other components (vertical supports, chains, rope, bearings, etc.) meet the safety requirements.
- **Stability Concerns:** Without the central vertical tube or diagonal bracing, the frame lacks

sufficient lateral stability, making it prone to racking and potential failure during use.

- **Verdict:** The structure is not safe in its current form due to the top beam's insufficient safety factor (SF = 1.81) and significant stability issues.

Recommendations for a Safe Design

To make the structure safe, we need to address both the top beam's safety factor and the frame's stability. Here are two options:

Option 1: Add Diagonal Bracing:

- Add outer diagonal bracing (40 mm x 40 mm x 2 mm, ~2155 mm, one per side) to connect the top beam to the vertical supports. Outer bracing reduces the bending moment by 40% (SF increases to 3.01).

Option 2: Upgrade the Top Beam to 50 mm x 50 mm x 2 mm (Minimal Changes)

- **Upgrade the Top Beam**:
  - Use a 50 mm x 50 mm x 2 mm tube (1524 mm long) instead of the 40 mm x 40 mm x 2 mm tube.
- **Recalculate SF**:
  - Section Modulus: $Z = 6315.9\ mm^3$
  - Bending Stress:
  - $\sigma = (560.72 \times 10^3) / 6315.9 \approx 88.8$ MPa.
  - SF: $250 / 88.8 \approx 2.81$
  - **Stability**: Without bracing, lateral stability remains a concern, but the top beam will be safe.
  - **Conclusion**: The top beam is safe (SF = 2.81 > 2), but stability issues persist.

VI. CONCLUSIONS

- **Design and Fabrication:** A sustainable playground swing was developed using a recycled 185R14 tyre, supported by a mild steel frame, M8 chains, and 10 mm nylon rope, successfully installed in an outdoor setting with a hexagonal paver base for stability.
- **Structural Analysis of Initial Prototype:** The initial design, lacking diagonal bracing and a central vertical tube, was deemed unsafe with a top beam SF of 1.81 (< 2–3) and exhibited lateral instability under a 2943 N dynamic load, highlighting the need for structural reinforcement.
- **Optimized Design for Safety:** Incorporating diagonal bracing and a central vertical tube increased the top beam SF to 3.77, ensuring compliance with ASTM F1487-17 standards and mitigating lateral instability, thus validating the revised design for safe public use.
- **Component Safety Assessment:**
  - ✓ M8 chains achieved an SF of 3.0 (conservative load).
  - ✓ 10 mm nylon rope yielded an SF of 3.33, outperforming cotton rope (SF = 0.80, unsafe).
  - ✓ Flat plates (355.6 x 25 x 4 mm) recorded an SF of 4.76 (tensile, conservative load).
  - ✓ M10 Grade 8.8 bolts demonstrated an SF of 25.62 (shear, conservative load).
  - ✓ All components exceeded the target SF of 2–3, confirming structural integrity.
- **Load Distribution Insight:** The branched chain configuration distributed the load to 735.75 N per bolt (normal) or 1471.5 N (conservative), maintaining the flat plates' SF at 4.76, underscoring the design's robustness under varying load conditions.
- **Cost-Effectiveness and Durability:** The design, costing 96.07 OMR, leverages recycled materials and anti-corrosion treatments, ensuring economic feasibility and long-term durability for community applications.
- **Implications and Recommendations:** This study demonstrates the viability of recycled materials in safe playground equipment, provided structural enhancements are implemented. Future work should focus on long-term durability testing and the integration of impact-absorbing ground cover to further enhance safety.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the University of Technology and Applied Sciences – Salalah for their invaluable support and funding.

REFERENCES

[1] ‘Swing (seat)’, *Wikipedia*. Feb. 18, 2025. Accessed: Mar. 28, 2025. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Swing_(seat)&oldid=1276350261

[2] P. Pal, T. Ride’n, B. Ride’n, and B. Buck, ‘Installation, Operation & Maintenance Instructions for all M&M Tire Swings’.

[3] ‘A Case Study of Egirdir Zero Waste Park for Living and Learning’, *Adv. Image Video Process.*, vol. 10, no. 4, Aug. 2022, doi: 10.14738/aivp.104.12857.

[4] T. D. Bow, ‘Ultimate Tire Swing’, Instructables. Accessed: Mar. 28, 2025. [Online]. Available: https://www.instructables.com/Ultimate-Tire-Swing/

[5] F15 Committee, *Consumer Safety Performance Specification for Playground Equipment for Public Use*. doi: 10.1520/F1487-21.

[6] ‘BS EN 1176-2:2017 Playground equipment and surfacing. Additional specific safety requirements and test methods for swings (Incorporating corrigendum October 2019), British Standards Institution - Publication Index | NBS’. Accessed: Mar. 28, 2025. [Online]. Available: https://www.thenbs.com/PublicationIndex/documents/details?Pub=BSI&DocId=327955

[7] P. Digital, ‘Rope materials: a beginner’s guide - RopesDirect’, Ropes Direct. Accessed: Mar. 28, 2025. [Online]. Available: https://www.ropesdirect.co.uk/blog/rope-materials-a-beginners-guide-to-different-types-of-rope/

[8] ‘Asbestos - Overview | Occupational Safety and Health Administration’. Accessed: Mar. 28, 2025. [Online]. Available: https://www.osha.gov/asbestos

[9] ‘Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds’, *EPA U. S. Environ. Prot. Agency*, Dec. 2016.

[10] ‘Experimental Determination of Mechanical Properties of Waste Tyre Bales Used for Geotechnical Applications’. Accessed: Mar. 28, 2025. [Online]. Available: https://www.mdpi.com/1996-1944/14/12/3310