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Developments on Baby Strollers over the Last Decade

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Authors' contributions

This work was carried out in collaboration among all authors. Author BXK performed a comprehensive review on the development of baby strollers over the last decade. Authors UN and MYY supervised the work and designed the contents in this article. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

It has come to attention that the interest of baby stroller design is still encouraged and popular among worldwide researches and consumers. A visual history and timeline of invented baby strollers from 1973 to today's baby strollers was drafted. Moreover, a ten years review on multiple designs of baby strollers was done ranging from the year 2008 to 2018. Based on the review, there are many possible ways to design a baby stroller which its sole purpose is to transport a baby in a much easier method. Through this review, it is noticeable that baby stroller inventors are implementing additional functions like rocking mechanism, diaper changing table, and others. The use of electronic devices in strollers is slowly implemented as the years increases, although there always potential ideas for improvements. Graphs and tables on baby strollers by their popularity and brand was drawn with online shopping websites as a resource to recognize consumer's interest. Besides that, potential improvements and ideas on the design and fabrication of baby strollers were suggested to fit in with the impending society and future generation.

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1. INTRODUCTION

The comfort and protection of one's child is every parent's responsibility and a desire to fulfil it. Baby strollers are essential for navigating life with your new baby as it helps to ease the burden of carrying the weight of a baby or toddler on long, or even -short walks. The development of baby stroller throughout the years have improved vastly and significantly, from the form of baby carriages to modern implementations of technology and gadgets. This section of a literature review and research will only be focusing on the designs and applications of baby strollers throughout the many years since it was first invented.

Fig. 1. First baby carriage invented by William Kent [1]

The very first baby stroller was invented in the year 1733 by a landscape architect named William Kent as shown in Fig. 1. The purpose of this invention was to transport the third Duke of Devonshire's children alongside to amuse them. Designed in a shell-shape, this carriage had a harness aimed to be pulled by animals like goats, dogs or ponies, with a spring suspension to secure a comfy ride for the baby. Back then, carriages then become a fashionable piece that only the wealthiest parents could afford.

A century later in the mid-1800s, the baby strollers have become an easier navigating transport for babies as the designs substituted handles for parents or nannies to pull the stroller behind her, with the baby facing forward instead of having animals do the pulling as seen in Fig. 2. It has been known that pushing is much easier than pulling as it takes a lesser strength and energy from one person. Hence, in 1848, baby stroller came to America and American innovator Charles Burton changed the original design of the carriage as presented in Fig. 3, so parents could push their children rather than pulling them. The baby stroller was not popular in the United States as inexperienced parents tended to come into contact with pedestrians. However, he managed to patent his designs at England with the name "perambulator", which may be referred now as pram.

Fig. 2. Carriage in mid 1800s [2]

In today's market, the seat of the baby stroller can be adjusted so that parents or nannies could have the child facing them or facing away from them, whichever they preferred. This improvement was done by African American inventor William H. Richardson as he patented his design in the United States in 1889. Richardson made changes to the carriage wheels allowing it to move independently compared to the previous non-independent wheels as shown in Fig. 4. This improvement makes the stroller moremanoeuvrable and convenient for parents.

Slowly, the evolution of baby carriages has been improving. Following World War I, the safety features on a baby carriages were introduced and updated [3]. Inventors in 1920 made special safety features like bigger wheels, deeper, more spacious, lower and sturdier frames. Having more space, and lower frames can prevent the baby from crawling out or decreasing the distance of the stroller and the ground if the baby

were to escape. In the 1930s, materials like plastic and rubber were common materials being used in manufacturing baby stroller while inexpensive chromes are used as an alternative to brass. By the 1950s, baby carriages are a must have for parents as affordable material and safety features are not just a fashion piece but also budget- friendly [4].

Fig. 3. The perambulator invented by Charles Burton [2]

Fig. 4. Baby carriage invented by Richardson [2]

Came the year 1965 when London design engineer Owen Finlay Maclaren invented the first umbrella stroller as seen in Fig. 5 after watching his daughter struggled with manoeuvring and travelling with her child and the stroller [5]. Hence, he invented a lightweight and collapsible structures like how an umbrella works as a new generation of baby transport. Maclaren strollers are still in the market to date. In 1984, baby strollers have been made convenient for jogging by replacing the tires to bicycle tires and design of three-wheeled for a steadier frame. These all was reinvented by Phil Baechler after receiving reviews from parents whose jogging is a hobby. Lastly, the last common features we can see in the market today is the double baby stroller developed by the stroller company Baby Jogger in 1986 as presented in Fig. 6.

Fig. 5. First umbrella stroller invented by Owen Maclaren [6]

Fig. 6. Baby jogger invented by PhilBaechler [7]

Today's stroller in the market has taken most of the original basic features like ergonomic designs, canopy, rotating wheels, foldable features, rotating seats, and umbrella strollers. The features are not limited to only the ones that have been stated as electrical enhancements such as lights, fans and chair warmers have been incorporated to current baby strollers as well. Fig. 7 shows the baby stroller with basic features in the market today.

Fig. 7. Baby stroller in market today [8]

How is a baby stroller, becoming a sophisticated baby transport to cater to the needs of babies in current society? With the current society where everything involves technology and electric components, society looks for an easy way to do things. When the baby feels hot or cold or even irritated, no fan, cushion warmer nor are repellents needed to be carried around. Why? Because everything is made easier with electrical components where it can be installed directly to the baby stroller. Strollers now provide great protection against scorching sun and UV rays as climates are drastically changing from time to time. What society is looking for its durability and a long-term investment. A good quality stroller is usually compliant with the firmest safety standards and is made from strong and durable materials. For example, if parents were to deliver a new-born baby, they will not be required to purchase another stroller as the existing one they had before can be used. This is a long-lasting option and it reduces cost greatly for the adaptation of society today. All in all, parents can feed their baby, entertain them and regulate baby's temperature with just a baby stroller.

There are tons of baby stroller on the market today as we all know it since it has been invented in the 1700s. Although the baby stroller has been here for centuries, it is still a piece that can be creatively improved and a big hit till today. A bar chart as presented in Fig. 8 shows the number of articles and reports regarding designs and applications of baby strollers. It can be generated through research to prove that baby strollers until 2018 is still trendy. As an engineer, it is our job to always innovate, invent and design to fulfil objectives and requirements. As shown in the results, baby strollers can still be improved in design and application wise as parents are still interested with it.

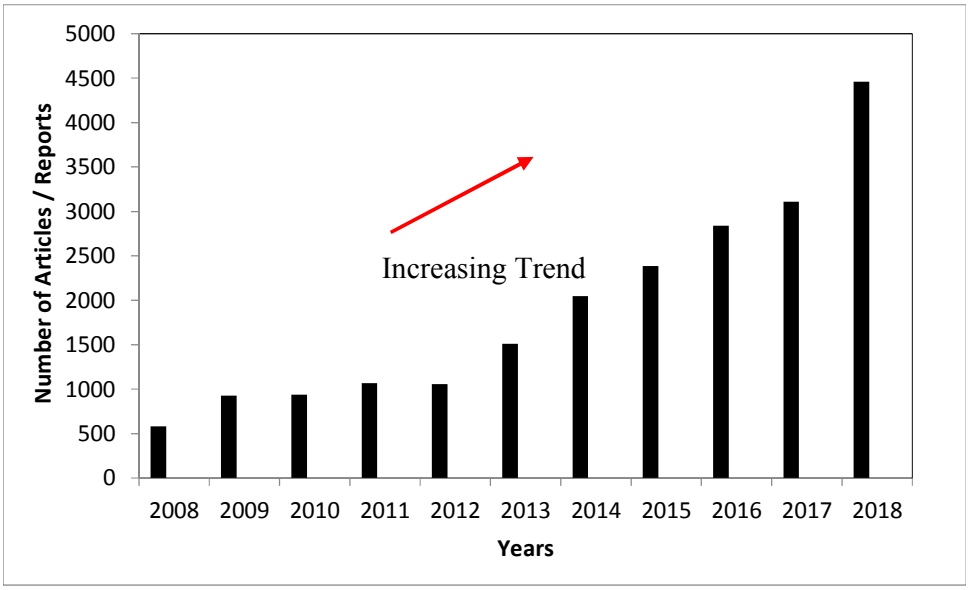


Fig. 8. Number of Articles / reports on baby strollers based on designs and applications for year 2008 – 2018

Source: Google Search Engine Keywords used: baby stroller, designs, application

From the above, it can be summarized that the development of baby stroller is still in great interest among worldwide researches and consumers. Hence, this paper intends to dedicate a comprehensive review on the improvement of the design and fabrication or an ergonomic baby stroller from the year 2008 to 2018.

2. PATENT REVIEWS

Year 2008

i) Kun Wang has designed a baby stroller as presented in Fig. 9 that includes a first frame, a second frame, and two third frames with front wheels connected to two ends of the first frame by two pivotable members. This baby stroller has various units, for example, folding, operation and adjustment unit. Folding mechanism was applied that can pivot the first frame inward and a rotation member as an operating unit which its job is to fold the handle. Adjustments units are applied for adjusting the seats. This baby stroller comes with a shade frame that is connected to the seat which can be extended or folded.

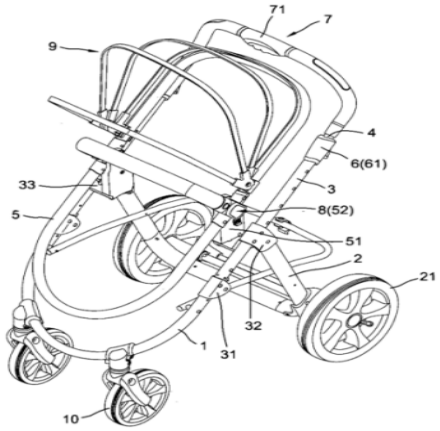


Fig. 9. Baby stroller invented by K. Wang [9]

ii) In Fig. 10, this baby stroller invented by Henry F.Thorne, Robert Daley, and Mary Koes have one or more components which are automatically and easily movable by a drive mechanism between an operative position for the stroller usage. It can be in a collapsed position for more storage and transportation. This baby stroller has an easy folding mechanism where the wheels can be tucked in [10–12].

iii) The child seat is positioned on the stroller frame as shown in Fig. 11. This baby stroller was invented by Robert Pike, Todd Sorzano, Gregory Sellers and Dmitriy Faktorovich. The stroller includes a child barrier that includes a cup holder horizontally. When the child barrier moves relative to the stroller frame, the cup holder pivots horizontally. The user can store their beverage as well as the baby's beverage instead of holding in their hand [13–20].

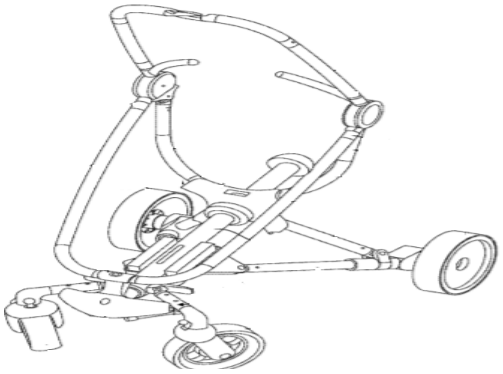


Fig. 10. Baby stroller invented by Thorne, Daley and Koes [10]

Fig. 11. Baby stroller invented by pike, Sorzano, sellers and Faktorovich [21]

Year 2009

i) Baby stroller in Fig. 12 was invented by Gerjan Storm. It is a rather simple design for a stroller frame, but it serves its purpose as baby transport system. It consists of three wheels with a baby seat attached in the middle. The seat is

attached at the centre of gravity of this baby stroller for better stability.

ii) A deployable side seat for a baby stroller as seen in Fig. 13 was invented by Marie Schutzendorf and Corbett Griffith. An optional removable side seat for a baby stroller, to seat a second child is secured by hand-operated connectors to nearly any baby or child stroller without using tools. The side as can see, it faces to the side to the stroller and has a deployed position in which two wheels are fixed in tandem on the side seat frame contact the pavement. The side seat can be folded neatly and compactly when not in use [23–25].

iii) This rather interesting baby stroller design as shown in Fig. 14 was invented by Martin Troup and Groner Troup. This baby stroller was made with the intention to allow the child to seat, stand or in reclined position. Moreover, it is fully collapsible. The stroller has opposing side walls, a front wall, a seat and a floor member suspended below the seat. This stroller is supported by four wheels, has a canopy, a standing space formed between a front edge of the seat base and the handrail to allow the child sufficient room for standing while holding the handrail [26–28].

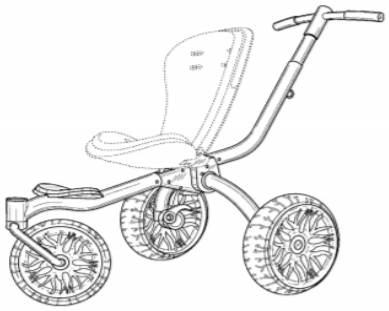


Fig. 12. Baby stroller invented by Storm [22]

Fig. 13. Baby stroller invented by Schutzendorf and Griffith [23]

Fig. 14. Baby stroller invented by Troup [26]

Year 2010

i) Inventor Jian-Qun Li designed a tandem stroller as in Fig. 15. The objective of this invention is to provide a tandem stroller that has a shortened length in a front -to-rear direction. The front seat includes a front seat plate disposed on the frame that can place beverages on it. Consequently, the total length of the stroller in a front to rear direction is shortened significantly [29,30].

Fig. 15. Baby stroller invented by Li [29]

ii) Fig. 16 shows a stroller that includes a frame having at least one front leg, one rear leg and at least one wheel mounted on each leg. The inventors are Jeff Greger and Michael Longnecker. The stroller includes a seat having a seat base and a seat back pivotally mounted to the frame. The frame for the baby seat is rather low and spacious to support the size of the travel attachment [31–33].

iii) Inventors Wes Thomas, Toriono Granger and James Morrow invented baby stroller in Fig. 17 with the purpose of having the child to seat or stand on this two in one stroller. The stroller includes a frame and a seat having a seat pan that is pivotable between a raised and lowered position. In the lowered position, the seat pan is to support the child in a seating position. The standing position is allowed due to the foot platform coupled to the frame [34].

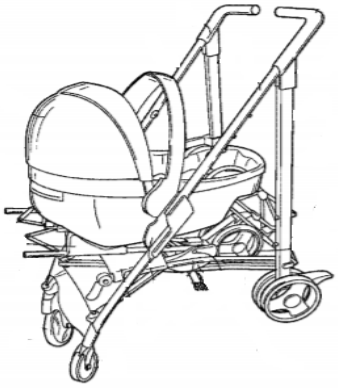


Fig. 16. Baby stroller invented by Greger and Longnecker [31]

Fig. 17. Baby stroller invented by Thomas, Granger and Morrow [34]

Year 2011

i) Gerald Gross has designed an illuminable baby stroller having embedded light sources as shown in Fig. 18 which can control the lights. LEDs are preferably used as light sources embedded in the frame of the stroller in translucent sections of the frames making the stroller visible in dim and dark lighting. This stroller includes a forward and rear light source that illuminates the path in front and the back of the stroller[35–39].

ii) The objective of this invention of baby stroller as shown in Fig. 19 is to overcome the shortcomings of the conventional stroller that has a handle bar that is not adjustable and a bulky shape that is difficult for storage. Chin-I Lai the inventor improved the shortcomings by including a handle set containing an elevation set and a folding set. The elevation serves its purpose by allowing adjustments to the length while the folding set allows the baby stroller to shrunk into a smaller size when folding [40–42].

Fig. 18. Baby stroller invented by Gross [35]

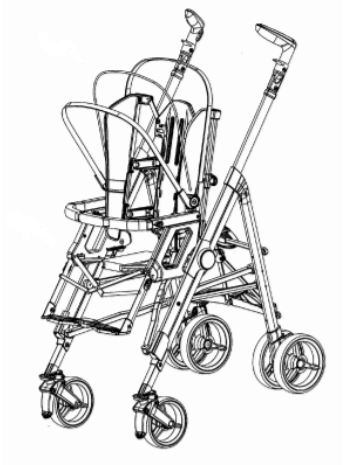


Fig. 19 Baby stroller invented by Lai [40]

Year 2012

i) This combined shopping trolley baby stroller in Fig. 20 was designed by HarriEktron. This baby stroller/cart includes a four-wheeled cross-shaped frame that carries a box-shaped basket and a child

seat. The basket can be changed to half volume and thus can form a child's seat used in the front seat of cart. The baby stroller seat can be removed to form a full shopping car to be used [43–47].

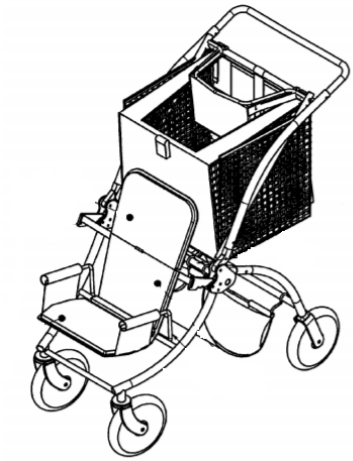


Fig. 20. Baby stroller invented by Ektron [43]

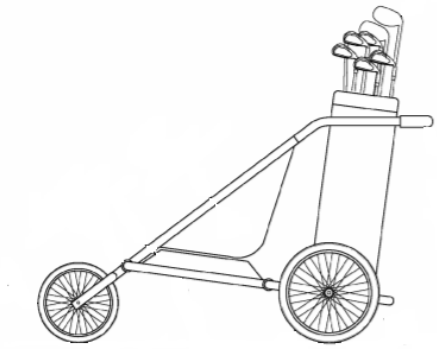


Fig. 21. Baby stroller invented by Joubert [48]

ii) Fig. 21 represents a stroller designed for people with interest in sports. The baby stroller was designed by Jean-Pierre Joubert with the idea of having an athletic accessory container built into the baby stroller. The baby stroller includes a frame having a front-forward facing seat for infants to be seated. An enclosure area is defined by a cross-member that spans the spaced apart frame members. An athletic container is carried on the support and extends through the enclosure area [48–51].

iii) Baby stroller presented in Fig. 22 is an automatically controllable smart stroller invented by Chih-Hsiung Yang. This baby stroller includes a frame, a body-movement detecting unit provided on the frame, a drive control unit and a drive unit. The drive control unit electrically connects with the body movement detecting unit and drive unit. The objective of this baby stroller is to provide an automatically smart stroller with a synchronous drive mechanism [52–56].

Fig. 22. Baby stroller invented by Yang [52]

Year 2013

i) This baby stroller in Fig. 23 was designed by Mark Zehfuss and Gordon Liao and was inspired to form a baby stroller with a stroller frame and a chair. The stroller frame has a rotatable base and the chair includes a folding joint such that the chair can be folded directly onto the stroller frame to provide a simple and easy quick operation to accomplish the effect of reducing the storage volume of a baby stroller. The chair may be mounted facing forward or rearward [57–60].

ii) The present invention as shown in Fig. 24 was invented by Cheng-Fan Yang, Chen-Tai Chang, Sheng-Po Hung and Fu-Peng Chou. This baby stroller can be extended horizontally and tucked back in. It is a convertible tandem stroller frame, especially to a convertible tandem stroller frame equipped with a release actuator mounted at the front end of it lock and un-lock a longitudinal telescopic mechanism [61–65].

Fig. 23. Baby stroller invented by Zehfuss and Liao [57]

Fig. 24. Baby stroller invented by Yang, Chang, Hung and Chou [61]

Year 2014

i) A rather unique baby stroller as shown in Fig. 25 was designed by Bradley James Mattarocci where it includes a platform that the child can stand on. This stroller consists of a frame, a plurality of wheels supporting the frame, a forward and rearward facing seat supported by the frame, seat back and platform positioned rearward of the forward-facing seat. The seat back helps to support the back if the child seated in the rearward facing seat in the rearward direction. In addition, the seat is moveable between a use and storage position to increase child's access to stand on the platform [66–69].

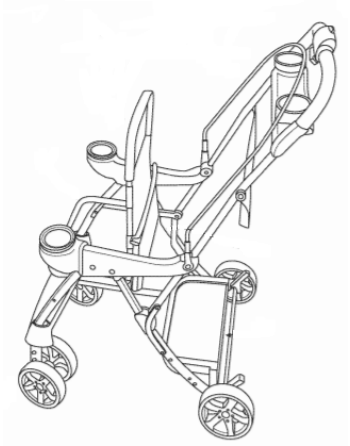


Fig. 25. Baby stroller invented by Mattarocci[66]

Fig. 26. Baby stroller invented by Storch [70]

ii) Baby stroller presented in Fig. 26 has a sole purpose of enhancing the safety of baby strollers by implementing a safety device that prevents runaway baby stroller. This baby stroller is very useful especially on rainy days as sidewalks can be slippery and pose a threat on the stroller wheels if person pushing the stroller stops and doesn't apply brakes. Baby stroller designed by Leonard Storch has improved the baby stroller by providing fully automatic slip-clutch joining means to inhibit veering off by automatically coupling the stroller's rear wheels together when the stroller is stopped. Once it has been coupled, the rear wheels must rotate in unison thus helping to prevent the stroller from veering off towards the curb. The slip clutch disengages when the stroller is being pushed [70–72].

iii) Baby stroller in Fig. 27 was designed with a purpose for better storage. Ryan Hawker and David N Foster are the inventors behind this baby stroller design. The seat-frame assembly can be rearranged at the option of the user to change from expanded use mode to a relatively narrowed collapsed storage mode [73–76].

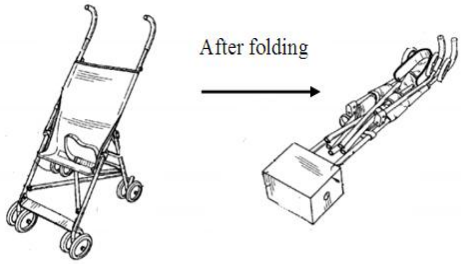


Fig. 27. Baby stroller invented by Hawker and Foster [73]

Fig. 28. Baby stroller invented by Gilbert [77]

Year 2015

i) Fig. 28 shows a baby stroller invented by Sean Gilbert that incorporates a lighting system to the stroller. The lighting system can be found underside of the stroller, compromising a fasten able light strip. A wiring harness fasten able to the frame of the stroller that is wire configured to electrically connect the light strip to the power supply. This baby stroller has a switch integrated to it to activate and deactivate the light strip whereby, when the it is on active mode, the ground beneath the baby stroller is illuminated.

ii) This baby stroller presented in Fig. 29 is a portable, foldable, baby-changing table unit is provided attachable to a baby stroller. It is invented by Daniel and MagdaliniPenello. This unit includes connectors for connecting the baby-changing table unit to the stroller's baby car seat connectors. A flexible changing pad to be attached to the portable baby-changing table unit includes a diaper receiver and a handy-wipe receiver [78–82].

Fig. 29. Baby stroller invented by Penello [78]

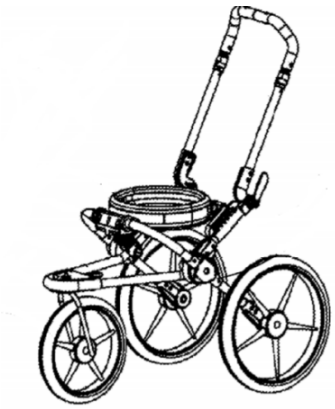


Fig. 30. Baby stroller invented by Leys, Santos, Hei, E.Bartz, Dudkowski, Maddox, and C.Wang [83]

iii) Baby stroller in Fig. 30 is a convertible jogger and all-terrain stroller invented by P. Leys, Santos, Hei, E.Bartz, Dudkowski, Maddox, and C. Wang. This stroller can be used in two modes which are for jogging and another for everyday use. The seat base is operable to suit the stated modes. The everyday mode has a relatively short base and high profile while for the jogging

mode have a long base and low profile. The baby stroller includes 3 wheels, one at the front and two at the rear [83–85].

Year 2016

i) This baby stroller in Fig. 31 was designed by Tsoung-Yong Liao and he has invented this with an expanded or folded mode. The sole purpose of this invention is to minimize storage space and for easier transportation by reducing the slide block and the couplings between components. This baby stroller is folded part by part to get a flat square like shape in the end. This stroller is packed with a lower frame, a slide block, a pull rod set, a rear wheel link rod and frame, first and second handle rod set, and a front wheel frame [86–89].

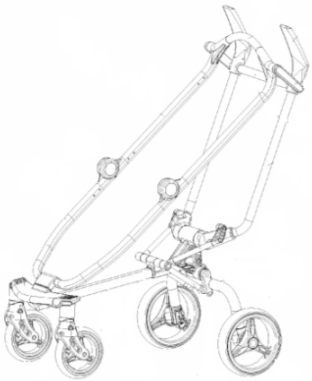


Fig. 31. Baby stroller invented by Liao [86]

ii) Provided in Fig. 32 below, this baby stroller special function is its folding mechanism that allows occupies less space, improve its portability facilitate its storage and transportation. This stroller is built upon couplings between the slide block and rear wheel rocker arms, the handling tube, an upper frame that assist in this expanded and folded mode. Tsoung-Yong Liao from Tainan is the man behind this invention [90–92].

iii) The baby stroller in Fig. 33 is a stroller with telescopic and locking members invented by Patrick Laffan, Leslie Stiba, and Hao Tian. A stroller comprising and additional storage area or child support system when expanded. The frames include a mechanism whereby the base of the frame is expanded backwards to create more storage space behind the baby seat. The stroller may include detachable wheels and handles or push bars that can assist in expanding and contracting the storage area [93–96].

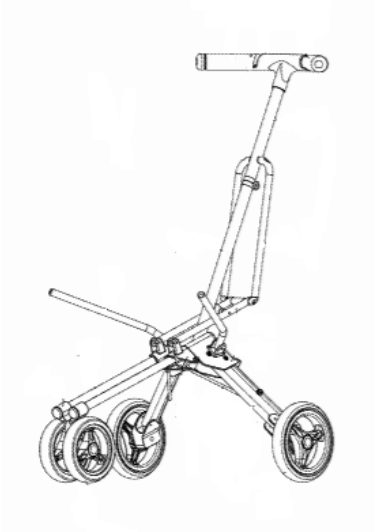


Fig. 32. Baby stroller invented by Liao [90]

Fig. 33. Baby stroller invented by Laffan, Stiba and Tian [93]

Year 2017

i) Corban Perry invented a motorized baby stroller as shown in Fig. 34 A motorized baby stroller for transporting a baby may include a front section, a side section connected to the front and back section. The front section includes a cavity to hold the baby and includes a proximity detector to detect a baby in the cavity and control the motors. It has a control panel that might include a switch and a battery meter.

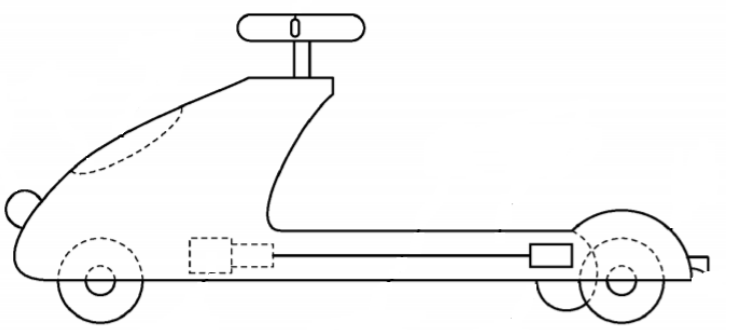


Fig. 34. Baby stroller invented by Perry [97]

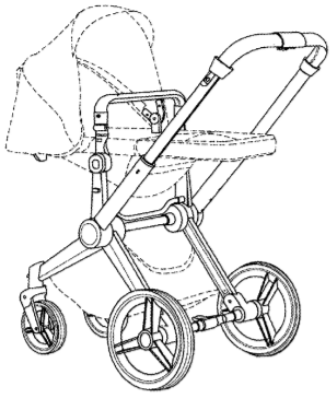


Fig. 35. Baby stroller invented by Gopaul [98]

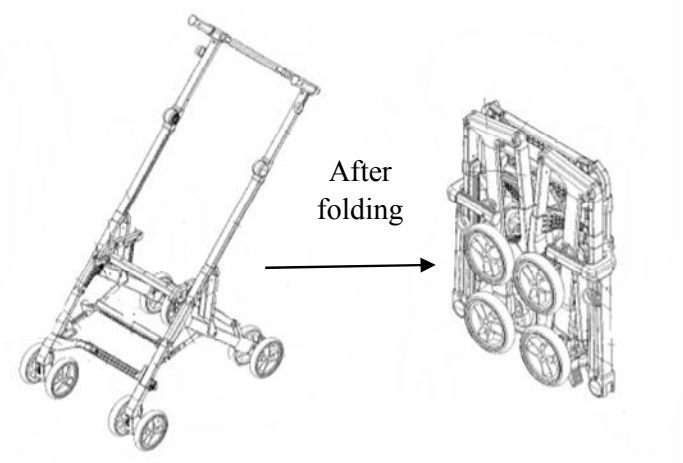


Fig. 36. Baby stroller invented by Qiang Zhang [99]

ii) Susan Gopaul invented baby stroller shown in Fig. 35 with basic features yet multifunctional. The seat can be facing in a downward or sleeping position for the child. It can be placed so that the baby can see the front view or the be seated to see the rear view [98].

iii) This collapsible baby carriage as shown in Fig. 36 was invented by Qiang Zhang. It includes a pair of middle pushing rod, a pair of upper pushing rod, a pair of T-rod, a pair of front wheel rod, a pair of bending-extension rod, a pair of side sliding rod, a pair of handles and a pair of seat side bending rod at two sides thereof. The baby carriage includes a folding mechanism. The folding mechanism turns the upper pushing rod upward and the middle pushing rod and the front wheel rod downward. The flipping mechanism flips the seat side bending rods, the bending-extension rods, the front wheel rods, the front wheels, the handles, the T- rods and the rear wheels inward, forming a flat and rectangular body [99–103].

Year 2018

i) Child stroller in Fig. 37 was invented by Kori Faith Duboff and Kimberly Mar Alicea. It includes a frame, a plurality of wheels, a child-seat assembly configured to rock back-and-forth with respect to the frame; a rocker assembly secured to the child-seat assembly. The rocker assembly includes a plurality of legs, each leg defining an undersurface, each undersurface being arced a rocker base, the rocker base comprises an inner surface. The stroller is configured such that when the child-seat assembly rocks back-and-forth with respect to the frame, the legs rock back-and-forth upon the inner surface of the rocker base[104].

ii) This convertible baby stroller in Fig. 38 was invented by Christy Hanson, Robert R. Roberts, Sienkiewicz, Travis Yoch, and Peter Young. A design that is rather unique because this baby stroller can be worn around the user's waist with a pulling rail that can attach to an adjustable running belt. An adjustable stroller having a main carriage and a handle bar assembly that is configured to allow the user to push or pull the stroller. A third front wheel is built for stability and balance reciprocating the two rear wheels attached to the main carriage. Furthermore, the adjustable stroller more specifically includes main carriage, pulling rails compromised of handle bar tubes and telescoping rail tubes, three wheels, a crossbar and a centre handle [105–108].

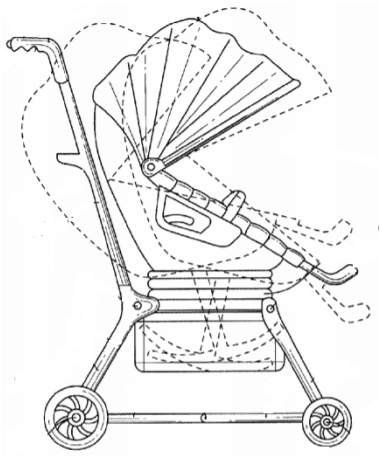


Fig. 37. Baby stroller invented by Qiang Zhang [104]

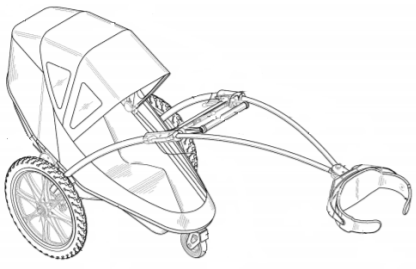


Fig. 38. Baby stroller invented by Hanson, Roberts, Sienkiewicz, Yoch, and Young [105]

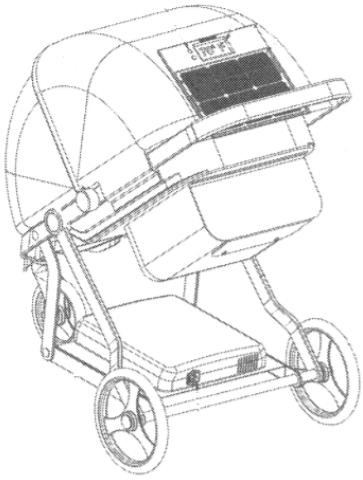


Fig. 39. Baby stroller invented by Abreu [109]

iii) Baby stroller in Fig. 39 was invented by Manuel Abreu with the intention to control the temperature of the baby stroller from

hot and cold weathers. This stroller is built with a frame, a seat on the frame for the child and a temperature controllable element which is adjacent to the seat. The temperature controllable element controls the temperature of an environment of the child. It provides plenty storage at the bottom of the stroller. The heating and cooling element is a continuous hollow tube for transferring air, liquid or gas [109].

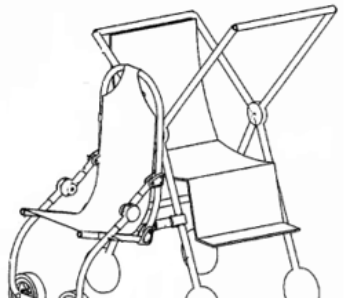
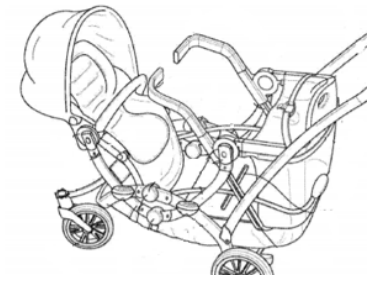
3. SUMMARY OF PATENT REVIEW

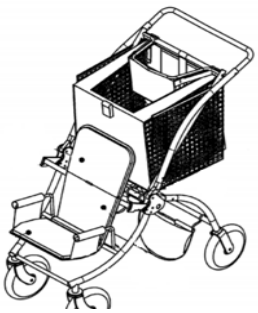
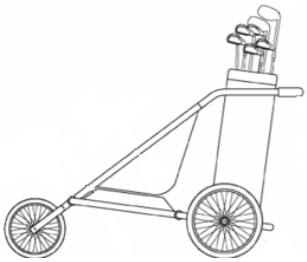
From the patent review of the year 2008 to 2018, there are a few characteristics and points that can be summarized on the design of baby strollers throughout these years. Some of the basic features and mechanism that is obvious on baby strollers are: canopy, foldable mechanism, ergonomic design and ample storage space. Next, improvements can be seen on the baby stroller as the year's increases is summarized in Table 1 respectively.

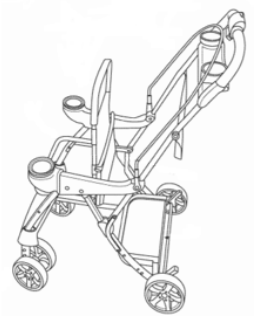
4. SURVEY ON PREFERRED STROLLERS IN MALAYSIA

Baby stroller has all the basic features that parents know of as stated in the section above. It can be summarized that the preferred baby strollers have characteristics like lightweight, multi-functional, ample storage, cup holders, safety features and importantly features that prioritized their child's comfort. A further research has been done as shown in Table 2 that focuses on baby stroller customers in Malaysia. This particular research is done to understand and learn in depth of parents' choice and preference on baby stroller. The source of research will be based on online shopping websites that are visited frequently by Malaysian customers.

Table 1. New implementation and improvements made on baby strollers

No	Implementation	Patent	Remarks
1.	Multipurpose Functions: Extra seating space	 Year: 2009 Inventor: Marie Schutzendorf and Corbett Griffith	An optional removable side seat for a baby stroller, to seat a second child. The side seat can be folded neatly and compactly.
2.	Multipurpose Functions: Stand and sit (2 in 1)	 Year: 2010 Inventor: Wes Thomas, Toriono Granger, James Morrow	A foot platform attached to allow the child to stand.

No	Implementation	Patent	Remarks
3.	Lights	 Year: 2011 Inventor: Gerald Gross	LED as embedded lights, forward and rear light source attached onto baby stroller.
4.	Multipurpose Function: Storage	 Year: 2012 Inventor: HarriEktron	Baby stroller includes and expandable shopping cart.
5.	Multipurpose Function: Storage	 Year: 2012 Inventor: Jean-Pierre Joubert	An athletic accessory container was built into the baby stroller.
6.	Automatic controller	 Year: 2012 Inventor: Chih-Hsiung Yang	An automatically controllable smart stroller which includes a body-movement detecting unit, a drive control unit and a drive unit.

No	Implementation	Patent	Remarks
7.	Multipurpose Functions: Stand and sit (2 in 1)	 Year: 2014 Inventor: Bradley James Mattarocci	A platform positioned rearward of the forward-facing seat to allow a child to stand on it.
8.	Multipurpose Functions: Changing table unit	 Year: 2015 Inventor: Daniel and Magdalini Penello	Baby stroller includes connectors for connecting the baby-changing table unit whichincludes a diaper receiver and a handy-wipe receiver
9.	Lights	 Year: 2015 Inventor: Sean Gilbert	Incorporates a lighting system that compromises a fasten able light strip. On active mode, the ground beneath the baby stroller is illuminated.
10.	Multipurpose Functions: Stand and sit (2 in 1)	 Year: 2016 Inventor: Patrick Laffan, Leslie Stiba, Hao Tian	The base of the frame is expanded backwards to create more storage space behind the baby seat, allowing the child to stand on it.

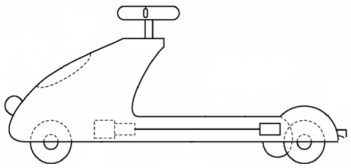
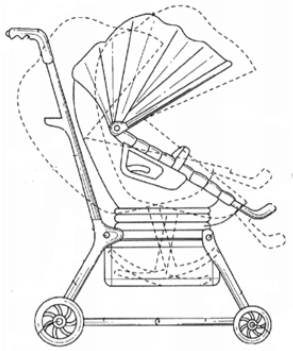
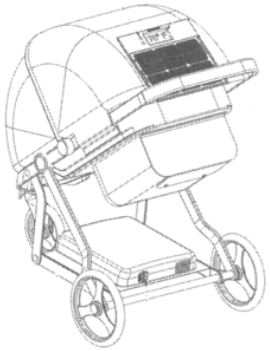
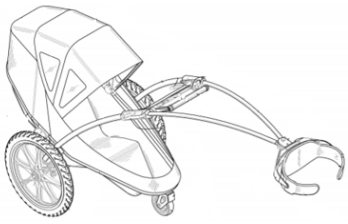
No	Implementation	Patent	Remarks
11.	Motorized	 Year: 2017 Inventor: Corban Perry	Equipped with a motor to operate the baby stroller.
12.	Multipurpose Function: Rocking Mechanism	 Year: 2018 Inventor:Kori Faith Duboff and Kimberly Mar Alicea	A rocker assembly secured to the child-seat assembly. The child-seat assembly rocks back-and-forth with respect to the frame
13.	Temperature controllable elements	 Year: 2018 Inventor: Manuel Abreu	A temperature controllable element which is adjacent to the seat was implemented. The heating and cooling element is a continuous hollow tube for transferring air, liquid or gas
14.	Modern design	 Year: 2018 Inventor: Christy Hanson, Robert R.Roberts, Sienkiewicz, Travis Yoch, Peter Young	A rather unique bay stroller design that can be considered as state-of-the-art design.

Table 2. Popular baby strollers in online shopping website, Lazada and Shopee

Brand	Rating (1-5 stars)	Features
 OSH 5 Wheels Magic Stroller	5	Foldable, adjustable aluminium alloy, regulating pedal, comfortable seat, Weight: 3.2kg
 GB Pockit Plus	5	Smart and ultra-compact folding, 5-position harness system, adjustable seatback, storage and canopy availability, self-standing when folded, one-hand push, Weight: 5.6kg
 Joie Pact Cabin	5	Compact fold, full-size canopy with eyeshade visor, UPF 50+ sun canopy, multi-position recline for backrest, full-size storage, 5-point harness, wheel suspensions, Weight: 6kg
 Little One 2 in 1	5	Foldable, tray with cup holder, large storage, additional baby car seat, one-hand folding system, lockable front swivel wheel, reclining seat, canopy availability with window, 5-point harness

 AMGO Detachable T1508	5	Foldable, shock absorption system, multiple reclining positions, canopy and storage availability, sun-proof fabric, top grade single-foot brake system, adjustable handle height, non-slip grip, 5-point harness
 Sweet Heart Paris ST230	4	Foldable, rocking mechanism, three-position backrest adjustments, washable and comfortable seat, adjustable handle, brakes availability, 3-tier canopy with mosquito net, Weight: 7.3kg
 ECOBEE	4	Foldable, multiple position seat recline, 5-point safety harness, lockable front swivel wheels, rear wheel suspensions, storage and all-weather adjustable canopy availability, brake availability, ultra-light, Weight: 3.8kg

Remark: 1 star implies least popular; 5 stars implies most popular
Source: Online shopping platform- LAZADA website; Shopee website; Keywords used: baby strollers, designs, popular

Table 2 as shown below is based on its popularity by customers in online shopping websites targeted in Malaysia. The baby stroller popularity is rated according to the number of stars, five stars being the highest. According to research, parents prefer strollers that have safety features, easy to store it anywhere, storage, canopy availability, and new-born ready. This can be proven by referencing to Table, as the baby strollers that are popular in online shopping websites fulfilled said criteria. This helps us to know what the focusing points when inventing or applying innovations to baby strollers. A few baby strollers, for example, baby stroller brand Sweet Heart Paris ST230 serves a multi-functional purpose, such as it can be used as a rocking chair. As the generation is evolving, new innovations and technological mechanism can be introduced to attract parents and baby stroller users.

Next, research has been done to recognize what are the popular baby stroller brands in our targeted location, Malaysia. As a buyer, a recommended brand is always reassuring because users will know if it's the right or close to the perfect choice for other users. Good brands that are highly recommended should be able to fulfil parent's needs in everything they hoped for in a baby stroller.

Chart presented in Fig. 40 are the few shortlisted brands that are popular in Malaysia. These trendy and highly recommended brands lean a little towards the pricier cost compared to the baby strollers on online shopping websites

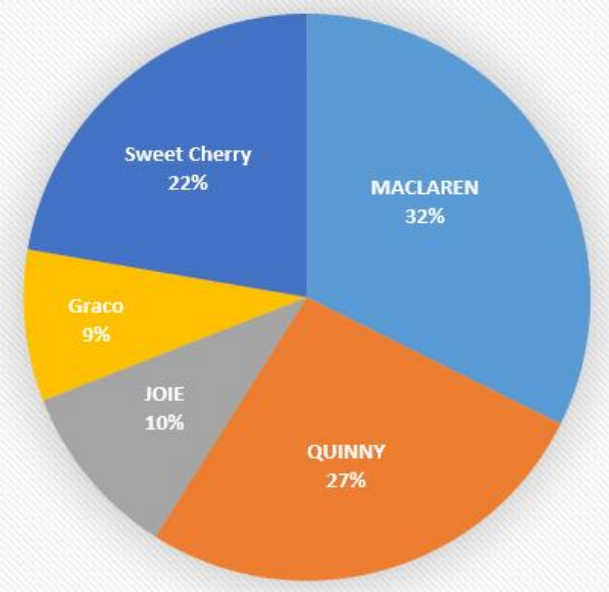


Fig. 40. Popular baby stroller brands in Malaysia
Source: Google Search Engine; Keywords used: baby stroller, recommended, popular, Malaysia

such as Shopee and Lazada. Nevertheless, of its price, it is still a popular choice among users in Malaysia. These baby stroller brands are referenced from various shopping websites where baby stroller can be purchased according to its brands. Top in the recommended list would be baby stroller brand Maclaren as it is the most suggested brands in Malaysia [110,111]. Maclaren was founded since 1967 and it's still a popular choice due to their variety of baby stroller selections. Maclaren products are customized for a variety of lifestyles, fashions, trends, and are proud of their safety and durability of baby strollers. Quinny is another brand to look forward to as it is a rather popular choice of baby stroller users. Quinny offers a variety of baby strollers that also serve multipurpose functions with its accessories. Other brands like Sweet Cherry, Joie and Graco as mentioned in the chart are also top choices among Malaysian users. Ergonomic designs and functions are the primary implications in these baby stroller brands.

To summarize this section, baby strollers with easy to like designs that must have basic features like canopy, storage, safety features and multipurpose functions are the most common choice among users. When inventing or making improvements, these baby stroller features must be taken into considerations to create an ergonomic baby stroller. In addition, since technical features and trendy items are still less implemented, it is recommended to consider such features to be added into baby stroller designs and applications.

5. FUTURE RESEARCH

Baby stroller design is still a topic of interest, and as an engineer, it is in our profession to look for ways to improve and innovate. There are still functions and potential ways to improve the design of existing baby strollers.

Baby stroller wheels are the base that maintains the stability of its chassis. An idea to combine present invention that are rather popular among generation today may be implemented. This invention can be served as wheels for the baby stroller and later be detached to be functioned as another purpose [66,112]. Safety features are needed as the wheels are crucial parts of the baby stroller. An easy locking system that can be controlled with a single part of the body to cater users especially ones with backache issues and usually pregnant ladies. Wheels that are not too tight yet safe to be manoeuvred with one hand, so users can multitask with the other hand. For tyres, shock absorber makes the bumpy ride to a smooth sailing and reduces vibrations acting on the baby and a user's hands.

Baby stroller users are usually in different heights. An adjustable height mechanism that users are familiar with, for example, mechanism that can

be seen on suitcases are to be implemented. Two kinds of handles may be enforced to ensure ease to users when they are given a situation where either one hand or two hands are to be on the baby stroller. Baby strollers should also be favourable for users. As seen in existing strollers, cup holders serve a good purpose. So, there will be improvements done on these cup holders.

The canopy is essential on baby strollers as they serve multiple purpose. Living in a tropical country, mosquitoes are very threatening. Existing baby strollers provide mosquito nets, but it is needed to be carried separately. The idea to combine the net to prevent from having the trouble to carry it separately or ends up forgetting to bring the mosquito net. A better viewing area can be done so that baby stroller users could look from behind at their child while pushing the stroller.

Fabrics to be used may be baby proof friendly to lessen the hassle of having to clean and washing it up frequently. It can be cooling and non-heat absorbent for the comfort of the baby and the user. Material for baby stroller handles may be heat resistant and capable of absorbing moisture, sweat and provides good gripping for the user.

Existing baby strollers have some lacking on electrically operated and necessary features. Multiple attachments can be implemented on baby strollers for fulfilling an ergonomic design and serve many positive purposes. Improvements can be made to these attachments, for example, adding more kind of attachments and having everything fixed in one solid attachment. The attachments should serve good and legit functions for the baby and the user. The new potential attachments can cater to the needs of babies by making them comfortable on hot weathers and allow the users to navigate baby strollers in a poor lighting area. Attachments may also entertain the baby much easier [113,35].

The seat is another crucial part of a baby stroller. There are many potential possibilities to improve the seat and seating area for the baby's comfort. The seats may be well ventilated and heated as per user's request for baby's convenience. Extra spacious compartments may be added in this area and the design of the baby seat should be able to support the baby's backbone. The seat may also have multiple positions that can be adjusted and incorporate the element of attachability for further purpose [110,111].

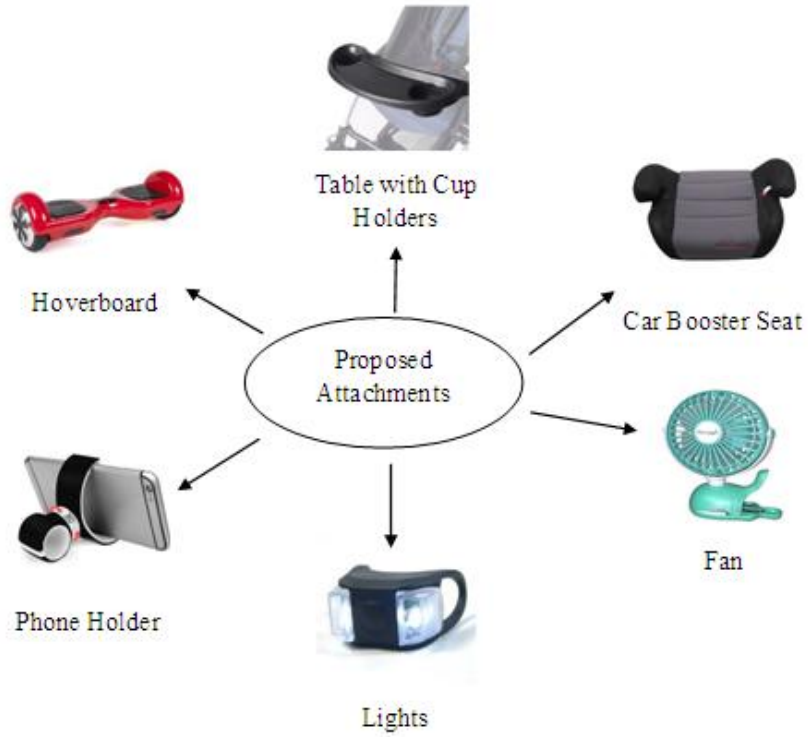


Fig. 41. Proposed attachments on baby stroller for various application

Safety features of this improved baby stroller shall meet parents' satisfactions. Shielding will be an important element in this category. Extra cushioning is necessary to protect the baby or child's fragile figure. Five-point harness system will be used because that is the best safety belts to prevent babies from falling or tripping. A mechanical device may be added to prevent bumpy rides and reduce vibrations acting on the baby and a user's hands.

It is important to know that there is always room for improvements and right ideas to achieve a new purpose of an invention. With the world moving forward to an era of smart technology, we are bound to succumb to future needs. Future inventions should be able to fit in with the impending society and generation. Thus, there are always potential ways to modify existing inventions to accord for the future.

The proposed attachments as presented in Figure 41 are a few of the attachments that are essential to a baby stroller. These attachments will benefit both the baby and user as it serves a practical purpose. The idea of combining four attachments into one whole attachment can be considered and implemented. By doing this, baby stroller users would not need to carry multiple attachments when they are in need of it. The attachments are modern and popular items used by society today especially the use of hover board.

6. CONCLUSION

Baby stroller design is still a topic of interest, and as an engineer, it is in our profession to look for ways to improve and innovate. There are still functions and potential ways to improve the design of existing baby strollers. A visual history and timeline of invented baby strollers from 1973 to today's baby strollers was drafted. Moreover, a ten years review on multiple designs of baby strollers was done ranging from the year 2008 to 2018. Based on the review, there are many possible ways to design a baby stroller which its sole purpose is to transport a baby in a much easier method. Safety features of this improved baby stroller shall meet parents' satisfactions. Shielding will be an important element in this category. Extra cushioning is necessary to protect the baby or child's fragile figure. Five-point harness system will be used because that is the best safety belts to prevent babies from falling or tripping. A mechanical device may be added to prevent bumpy rides and reduce vibrations acting on the baby and a user's hands. Graphs and tables on baby strollers by their popularity and brand was drawn with online shopping websites as a resource to recognize consumer's interest. Besides that, potential improvements and ideas on the design and fabrication of baby strollers were suggested to fit in with the impending society and future generation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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