



A Comprehensive Review on the Development of Car Booster Seats for Children

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Authors' contributions

This work was carried out in collaboration among all authors. Author IN performed a comprehensive review on research and developments of car booster seats for various applications. Author UN supervised the work and designed the content layout for this article. Author PKN proposed future research pathways on the subject of interest. All authors read and approved the final manuscript.

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ABSTRACT

Over the past decade there has been a deeply troubling increase in the number of vehicle traffic fatalities involving children. Owing to this, many researchers have contributed to research and development on car booster seats for children. In view of this, the current work encompasses a compilation of articles reviewed on car booster seats for children ranging from the years 1988 to 2018. Further than that, this work also provides information relating to the varying designs and specifications of car booster seats. Concurrently, the writers also propose potential future research that could be undertaken in relation to the developments in child car booster seats, which in turn may allow for new research pathways in this area of interest. Finally, taking into consideration the design and safety factors of the current market trend car booster seats for children, the writers also propose possible state of the art car booster seats for various applications.

Keywords: Ergonomics; child booster seat; child safety; multipurpose; future developments.

1. INTRODUCTION

There has been an increase in substantial design knowledge of car booster seats from 1988 to 2018. These designs are now reviewed to recognize and appreciate the flaws and benefits of each design. There are several ways to transport children from one place to another. And this varies in every country. Child transport in its initial sense began as a way to ease multitasking. But it has today become essential for all parents. Parents who practice the use car booster seats for their children from early on it self, experience a hassle-free and safe journey for their child.

Car accidents are the leading cause of death in the world. And this is especially so in Malaysia. This is due to the negligence of parents towards the safety of their children. To illustrate, several types of this negligence include: the improper use of child restraints, a lack of knowledge pertaining to child safety especially when in a car etc. According to the World Health Organization's (WHO) Global Status Report on Road Safety [1], children who are not subject to child restraints whilst in a car are the most exposed to the risk of danger including serious injury and death when involved in car accidents. Moreover, children around the ages of 0 months to 8 years are most susceptible to a multitude of injuries in a crash when they are unrestrained or improperly unrestrained [2]. An unrestrained child around the ages of 0 - 6 years old is exposed up to 5.4 times more greater risk of suffering a catastrophic injury, especially serious head injuries and spinal-cord injuries as compared to those restrained [3].

The risk of injury to children that has significantly decreased in developed nations as compared to

developing nations is an interesting observation that demands further examination [4]. This conundrum has not improved in developing nations mainly due to the unstable financial climate of developing nations, especially the Asian countries. This has hindered stricter of law enforcement on, and better maintenance of, roads. The increase in child and adolescent morbidity and mortality is being blamed on accidents [4]. In addition, the higher rate of accidents also seriously impacts and affects medical, economic, property and most importantly, human cost. Vehicle traffic fatalities reported on children from year 2007-2018 is portrayed in Fig. 1. Fig. 1 shows that vehicles fatalities involving children were reduced by 27% from 2007 to 2018, but increased by approximately around 8% from 2015 to 2017, and slightly reduced by about 4% in 2018 again [5]. This may be due to parents neglecting the safety of their child, which led an increase in the percentage from 2015 until 2017. On an average, three children are killed every day in the United States due to car accidents.

A booster seat is defined as a child restraint that may be attached or dismantled at any desired time, and is located in the vehicle and works as a lifter so that the lap and shoulder harness is well mounted across the hips, chest and shoulder of a child [7]. A child car seat booster is a car seat suitable for a child around the ages of 6 months to 12 years. However, for the purposes of this study, this range is narrowed down to the range a toddler which is approximately from around 4 years old to 12 years old. Backless child booster seats are the most suitable for toddlers as there is no need to support their head posture and allows for higher flexibility on body posture. A child is ready for a booster seat when their weight and height has outgrown their limit which is commonly around 16 kg to 33 kg in weight

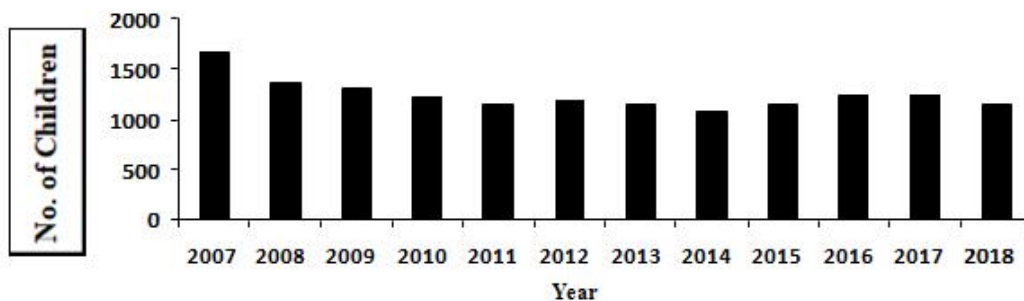


Fig. 1. Vehicle traffic fatalities reported on children from year 2007-2018 [6]

Table 1. Ideal weight and height according to age

Male		Age (year)	Female	
Weight (kg)	Height (cm)		Weight (kg)	Height (cm)
3.3	50.5	At the time of birth	3.2	49.9
6.0	61.1	3 months	5.4	60.2
7.8	67.8	6 months	7.2	66.6
9.2	72.1	9 months	8.6	71.1
10.2	76.1	1	9.5	75.0
12.3	85.6	2	11.8	84.5
14.6	94.9	3	14.1	93.9
16.7	102.9	4	16.6	101.6
18.7	109.9	5	17.7	108.4
20.7	116.1	6	19.5	114.6
22.9	121.7	7	21.8	120.6
25.3	127.0	8	24.8	126.4
28.1	132.2	9	28.5	132.2
31.4	137.5	10	32.5	138.3
32.2	140.0	11	33.7	142.0
37.0	147.0	12	38.7	148.0

and 102 cm to 142 cm in height, regardless of gender. The ideal weight and height for both genders according to their ideal age is illustrated in Table 1. Table 1 shows the relationship between the ideal weight and height of children according to their gender. According to the law, it is mandatory for every child below 36 kg in weight and 150 cm in height to use a child restraint system which has to be suitable for their height and weight when travelling in any vehicle, but a taxi [8].

A child who is not subjected to a seatbelt, nor a car booster seat or are placed on the parent's lap; are at a very high risk of being hurled forward through the car window with a force of up to 30 to 60 times that of their body weight, when the car is travelling at a speed of merely 50 km/h [8]. These days, parents tend to put their child on their lap due to a lack of awareness of safety measures, and by doing this they also violate laws pertaining to child safety. This is one of the main reasons for the statistics that show 262 children lost their lives on the road and 1, 107 children were seriously injured during the same period between the years 1996 to 2012 [8,9]. However, the updated statistics now show that the number of children killed was over twice in the year 2014 as compared to 2013. This number and statistics shows that the importance of the use of car booster seat for children on regular basis to protect lives and they also indirectly reduce the number of children killed on the road. To add, children are naturally highly

curious beings. Hence to avoid them from wondering around in the car, which may disturb the driver as well, booster seats are the best solution. This could also allow the child to comfortably enjoy the view on the outside.

There are certain standards and recommendations already in implementation for choosing the appropriate car booster seats for children based on their weight and height. For booster seats, previous recommendations entail that the child needs to use a booster seat until they reach at least 36 kg (80 lbs) in weight or 145 cm in height [10]. However, the new standards recommend that a child may already require a booster seat when they reach the maximum weight or height limit of their facing-forward car seat. This limit is usually stated by the car manufacturer [11]. But both parents usually overlook and neglect an extra safety measure for their child - the seat belt. In their mind, it is safe enough to use a regular seat belt. However the injuries sustained by a child may be reduced up to 45% for children between 4 to 8 years old when they use booster seats with a lap and shoulder strap belt [12]. The logical reason for this is that the booster seats lift the children up higher so that the children skeletal parts of the body, for example their hips and chest are strongly secured by the seat belts. For example, the hip part is depicted in Fig. 2. Fig. 2 shows the proper and improper ways of using a seat belt. As observable, the above part shows that an improper way of a using seat belts could cause

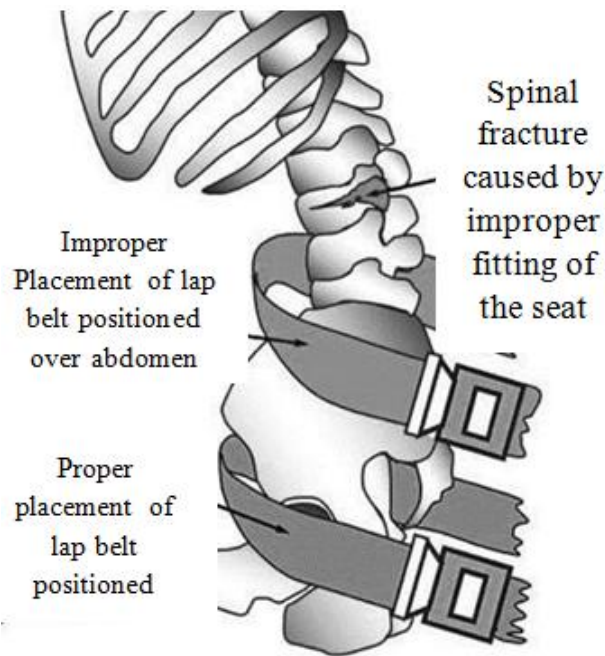


Fig. 2. The condition of body parts in proper and improper seatbelts [11]

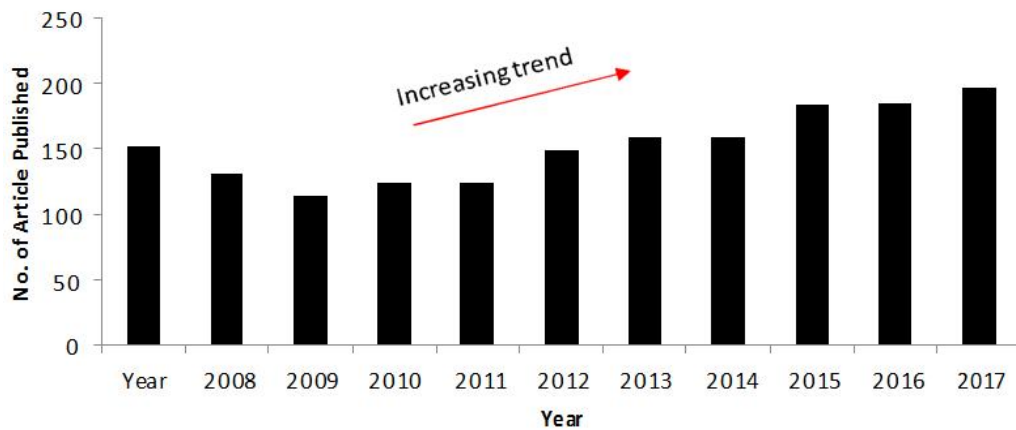


Fig. 3. Number of article published based on children car booster seat

Source: <http://www.ScienceDirect.com>. Keywords used: car seat, child booster seat

soft bone injuries and injuries to vulnerable parts of children. For example, it can increase the injury on the body such as spinal fracture, stomach, neck, etc. However, the bottom part of the picture show us the proper placement of belt whereby it protects children from being flung out of the car when accidents happen.

The previous decade witnessed a keen development in car booster seats for children. Intensive research was conducted on the

progress of car booster seats. Fig. 3 illustrates the number of articles published on research works in the development of car booster seats for children over the last decade. It indicates an increasing interest of global research into the topic.

Various modifications and adjustments were implemented from the time when the first car was manufactured and available in the market in the early 1900's. This were made in order to

safeguard those who drive and ride motorized vehicles. But at that time, most restrained system were designed to protect only adults without considering young children. Car seats for children began to be mass-produced only in the early 1930's. However even then, the car seats for children were not designed to secure the safety of children, but to act as a higher seat that allowed children to look out of the window without being confined to their seat. It was not until 1962 that the first seat which focused on the child safety system was invented independently by Jean Ames from the United Kingdom. The inventor created a rear-facing child seat with a Y-shaped strap and improvised by American Leonard Rivkin, of Denver Colorado who created a forward-facing seat with a metal frame.

The first invention of the car seat manufactured by the Bunny Bear Company in 1933 [13] is shown in Fig. 4. The main objective of this invention was to restrain the child from strolling around in the car by elevating the child's level so that their attention could be distracted by the view outside of the car. However, the design was to secure the child in the seat without taking into consideration the comfort of the child.



Fig. 4. Invention of the first car seat [13]

Car booster seats in the 1960's are depicted in Fig. 5. Fig. 5 illustrates the improvised version from the first booster seat that was invented by the Ford Motor Company in 1968. The design was built using a plastic-molded chair known as the "Tot-Guard" [14]. The plastic chair was devised with a cushion positioned to protect the child's face in the event of a crash.

The group also produced a pamphlet titled "Don't Risk Your Child's Life" in 1970's and in the same year, the National Highway and Traffic Safety

Administration (NHTSA) implemented the first Federal standard that made it mandatory for safety seats to be fastened into cars [15]. The car booster seats in the 1970's are portrayed in Fig. 6. Fig. 6 shows the booster seats in 1970's when the NHTSA began issuing standards and regulations for child safety seats such as all seats had to be anchored by the vehicle's seat belts including a harness to restrain the child [15].



Fig. 5. Car booster seat in year 1960's [14]



Fig. 6. Car booster seat in year 1970's [15]

Henceforth, in the year 1985, the evolution of the car booster seat was continued by the International Manufacturing Company [15]. This company took the initiative to contribute to the federal laws regulations wherein, the law required children of certain ages to use the car safety seat. The car booster seat in the year 1985 known as Astroseat VI Car Seat is depicted in Fig. 7. Fig. 7 illustrates that the car seat was built with additional featured such as a pull down harness and protective upholstery to comfortably support the child.



Fig. 7. 'Astroseat VI' car seat [15]

In 1990's, the ISOFIX anchors standard was introduced which known as the LATCH (Lower Anchors & Tether for Children) [15]. Federal law however did not mandate the use of the LATCH system in all vehicles until 2003. The car booster seat built together with the ISOFIX system is shown in Fig. 8. Fig. 8 shows that this system was made with a top tether point and lower anchor points to increase stability.

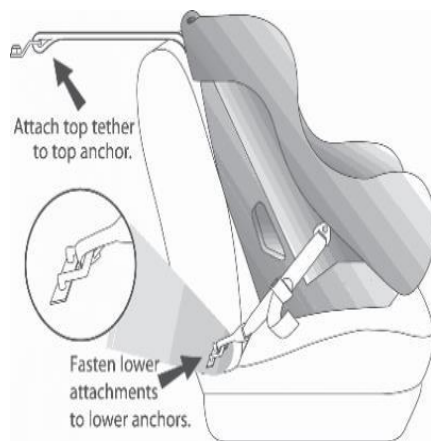


Fig. 8. Car booster seat incorporated with ISOFIX system [15]

These days various associations from various countries mutually put in effort to maximize efficiency by continuing intensive research and by increasing enforcement of rules and legislations pertaining to the safety of the passenger, especially children.

From the above it can be seen that the number of fatalities reported involving children from vehicle accidents has been increasing over the years in an alarming state. A minimal impact could lead

to greater injury especially on the spinal area if children are not properly restrained. The most affected column is the lumbar number five (L5) and sacrum column 1 (S1). This areas are particularly vulnerable to misalignment, 'wear and tear', and injury. Following this, guidelines have been implemented that show the right way to use proper safety equipment like the child booster seat related to the proposed ideal weight and height according to the age of the children age as per mention at Table 1.

As a result, there has been substantial interest and a large number of researches conducted over a last decade on child car booster seats. The number shows an increasing trend. Following this, this paper focuses on a review of car booster seats comprising of the design and specifications, advantages and disadvantages of an existing product and ways to mass-produce. This paper also review the design patent from the years 1988 to 2018. Further, some state of the art designs are proposed and discussed in this review such as the improvement of the existing car booster seat for children, adding a new feature to the improve the child booster seat, and ergonomics multipurpose.

2. REVIEW OF CAR BOOSTER SEATS

In modern day there are many options of booster seats available in the market. Each design offers a different type of detail, level of ergonomics, and various kinds of protection systems etc. But usually, boosters with high level child restraint systems and that are ergonomically comfortable, cost more money. However, the harness of the booster seats protect children from being flung out of the vehicle when an accident happens. During a crash the booster seat will also absorb and reduce the shock or impact force towards the child as the vehicle itself experiences a great momentum during the collision. This is the importance of choosing an appropriate and correct booster seat according to the child's weight and height in order to ensure all mechanisms implemented on the booster work properly when an emergency happens and that the child are less likely to be killed or injured during the crash.

Child restraint systems are typically classified according to the weight, height and age of the child in order to find the appropriate restraint. But in most cases, the main focus is on the weight of the child as different children

developed differently owing to different lifestyles. Charlton et al. has postulated the first understanding on how children behavior in vehicles. For example, when sitting in a car, there is restricted knowledge of how the size of the side supports affect the seating position. The child's seating position depends on the design of the restraint system in which the child is capable of moving. Therefore, most designs advocate the range of the sitting position.

There are different types of child safety seats or child restraints system for different sizes and ages. Examples include infants seats, convertible seats, combination seats and booster seats. Furthermore, infant seats are made particularly for infants which are smaller in size and have carrying handle bars for carrying and loading purposes. These seats are created for infants around 10 to 15 kg but depend on the model.

The convertible seat is typically suitable for children weighing 2.3 kg to 23 kg. This seat is designed for rear or forward facing positions. The rear facing position can be used for children until their weight exceeds 9.1 kg. There are research findings and crash tests that indicate rear facing seating positions are less harmful and safer for children. Additionally, other types of seats include combination seats or the five-point booster designated with forward facing seating positions in which it has a five point harness system. Also, the combination seat can be adjusted to a belt positioning booster by detaching some webbing.

The other type of belt positioning is the low back or no back booster. The main differences between the low back and the higher back are the head support and improvised safety towards side impact collisions. The booster seat was designed with a bench seat and with no head rest needed. The idea of the booster seat is to elevate children weighing around 18 to 45 kg, to a certain height so that the shoulder strap rests on the shoulder blade and not disturb the child's neck.

In essence, there are numerous options these days in the world of child safety seats. Most of the time, the materials used to manufacture and process these different seats, are the same. The assembly of the booster seat is done with loads of polypropylene pebble size pellets. Polypropylene is known as a tough plastic that stretches under certain pressures so that it will not easily crack like other plastics. One part of

the booster seat is known as padding where foam makes up the padding of the individual seats and is comprehensively measured to meet the Federal Motor Vehicle Safety Standard for flame resistance and energy absorption. The cover is made of vinyl and fabrics together with the harness. Both the cover and harness must be able to withstand a flammability test and be washable friendly. Apart from that, the thread used to seam this materials together must meet the same requirements. In detail, child safety seats consist of foam padding, fabric covers, a harness, and buckles or attaching mechanisms. The smaller mechanisms or parts such as the buckle latch plates, harness adjusters, locking clips, and buckles: are typically manufactured by specialized manufacturers like the Indiana Mills Company. Moreover, print paper is one of the more important specifications in the booster seat. Labels are constructed according to the Federal Standards such as precise wording, locations of labels device, and the paper must be able to withstand tears. All the important information must meet the requisite standards, and child safety seats must also be built together with the permanent storage in order to place the instructions.

The entire manufacturing process of the car booster seat is portrayed in Fig. 9. Fig. 9 shows that the design of car booster seats began with the desired design drawn using the CAD software. Next, simulation begins with molding process set out with the pebble size plastic pellets melted and transferred to the injection mold in order to form the shell. Then the shell is trimmed, cleaned and delivered to the assembly line as soon as it cools down. Afterwards, along the assembly line, the components from outside suppliers such as the buckle latch plates, harness adjusters, locking clips, foam padding and others are dispersed to the work stations. Then, the shell is attached with the padded cover and the buckle assembly is locked to the shell while the harness is threaded through the buckle, adjuster and harness retainer. The label is attached to the safety seat and the instructions are placed on the storage compartments of the seat. After the prototype is ready, the process continues with a crash test before it is sent to the packing line, to satisfy quality control standards and performance reviews. Finally, the seats are ready for mass production where they will be packed in cartons at the packing departments. It conveys the information to the users and designs created by marketing and advertising.

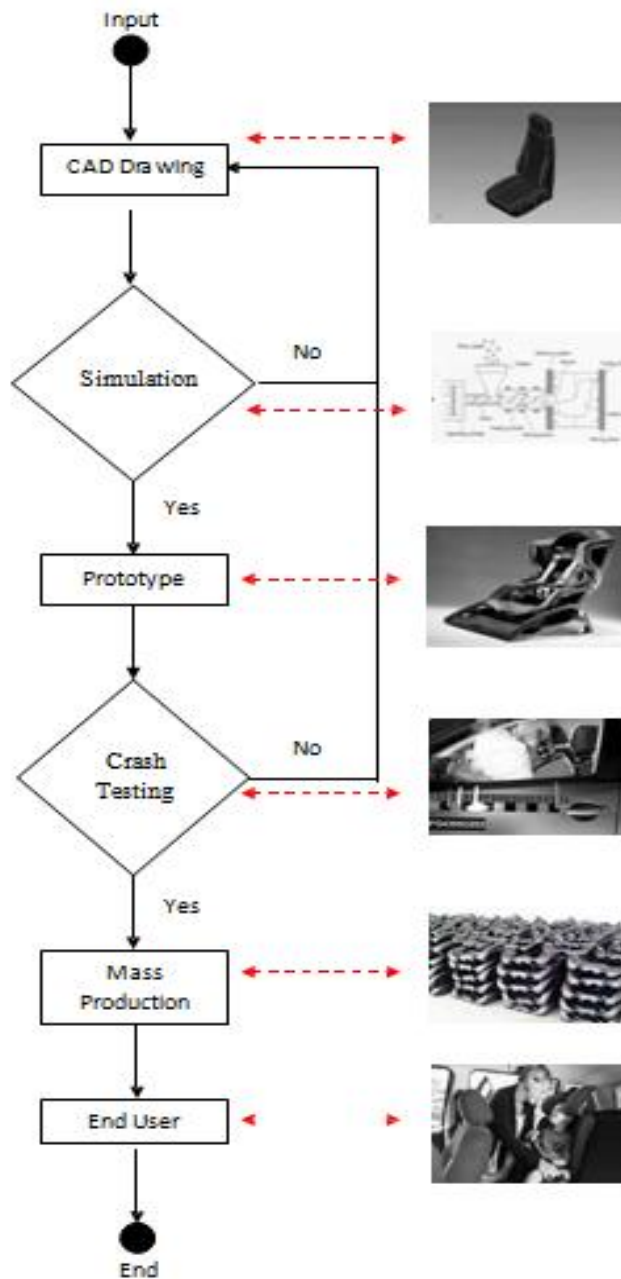


Fig. 9. Schematic illustration of ‘Design of Experiment’ on car booster seats production

3. PATENT REVIEWS

3.1 Year 1988

The complete design as seen in Fig. 10 (a) is invented by James M. Kain, with the patent number 4 754 999 and was published in 1988. The inventor claimed that the booster seat consists of two basic parts. Fig. 10 (b) illustrates the first base comprising of a base, frame and

back wherein the frames mounted on the first base and the back are pivoted on the frame [16]. Whilst Fig. 10 (c) shows that at the second base, a removable seat secures the base adjacent [16]. The well-secured booster seat is suitable for infants and small toddlers whereas the removable booster seat is apt for larger children. Harness straps including a crotch strap are provided to safeguard at the frame and passing through the back.

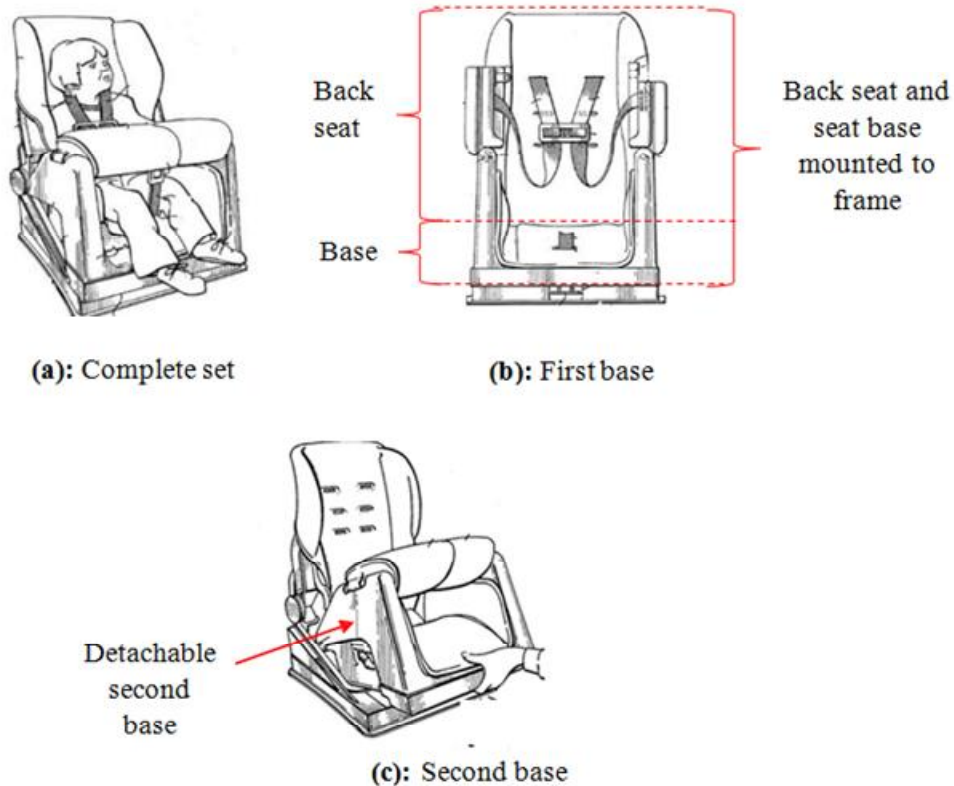


Fig. 10. Proposed design of child booster seat by James M. Kain [16]

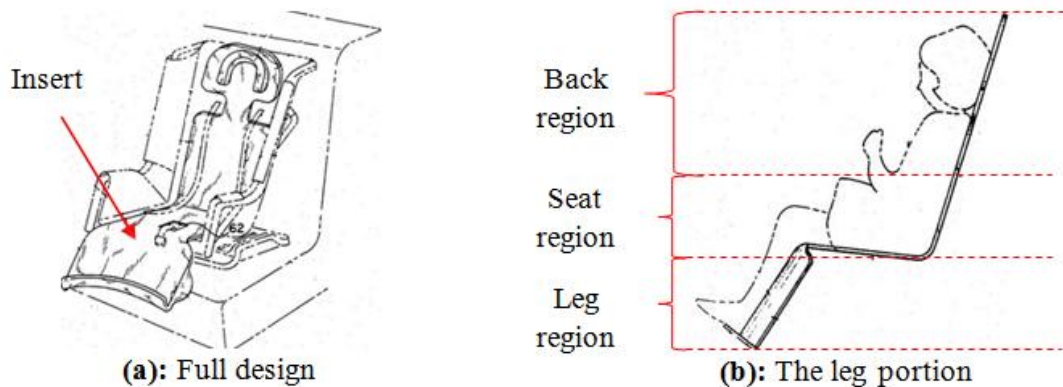


Fig. 11. Proposed design of child booster seat by Robert P. Hazel [17]

3.2 Year 1993

The design as seen in Fig. 11 (a) is invented by Robert P. Hazel, with patent number 5 228 745 and was published in 1993. The inventor claimed that the booster seat contained an insert which comprised of a back portion, a seat portion and a leg portion [17]. The insert helped the child's feet and legs that were supported by the leg portion

as depicted in Fig. 11 (b) [17]. It could also avoid the leg of the child from being cut off and help prolong the time the child remained seated. It contributed to the comfort of the child and acted as a guard for both the child seat and the seat of the car. Additionally, the invention also offered an easy and hassle free method of installing and removing the insert from the existing child or the child car seat.

3.3 Year 1995

The design as seen in Fig. 12 is invented by Matthew H Silverman, with patent number 5 385 385 and was published in 1995. The inventor claimed that the booster seat had sufficient inflexibility to endure high levels of compression and was soft and comfortable for the child occupant [18]. The objectives of conflicting safety design are achieved by creating the center of the booster seat from rigid Styrofoam. The foam is covered with a thin layer of soft urethane foam for comfort in which the foam permits the child seat to bend over and conform to almost any angle.

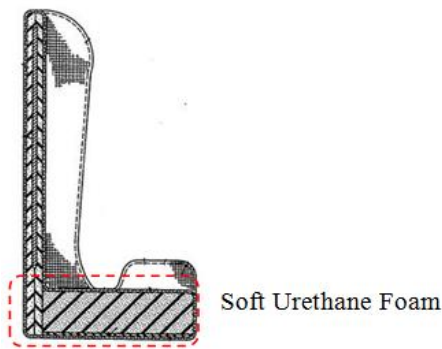


Fig. 12. Proposed design of child booster seat by Matthew H. Silverman [17]

3.4 Year 1996

The design as seen in Fig. 13 is invented by Jimmy M. Coursey, with patent number 5 511 850 and was published in 1996. The inventor claimed that the car booster seat consisted of an L-shaped frame, a seat portion and a backrest portion. Apart from that, the padded C-shaped bar is attached to the L-shaped frame so that the safety bar is in a horizontal position which is parallel to the seat portion [19]. It also contained a pivoting contrivance for connecting the first end of the safety bar to the side of the L-shaped frame.

Fig. 14 portrays the invention from the inventor known as Mark A. Sedlack with patent number DES.365.691 and it was published in 1996. The inventor claimed that the invention is the patterned design for a child booster including the vehicle lap belt system [20].

3.5 Year 1997

The design as seen in Fig. 15 is invented by James M. Kain, with patent number 5 685 604

and was published in 1997. The inventor claimed that the child restraint system was comprised of a seat, a movable barrier guard, and a shield lock plate. The purpose of the shield lock plate is to permit the user to choose the pivot of the movable barriers guard in order to access the right side or left side of the booster seat. The car booster seat contained the coupling mounting portion of a cup holder [21].

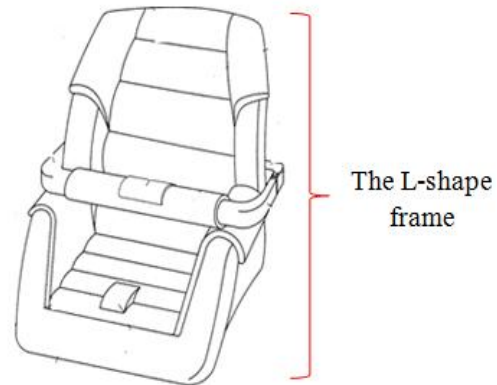


Fig. 13. Proposed design of child booster seat by Jimmy M. Coursey [19]

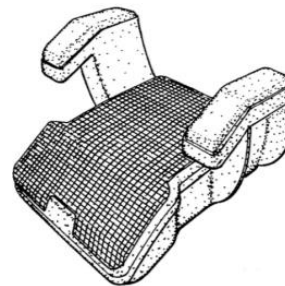


Fig. 14. Proposed design of child booster seat by Mark A. Sedlack [20]

Fig. 16 portrays the invention from an inventor known as Stephen Sher with patent number 5 678 887 and published in 1997. The inventor claimed that the booster seat contained an appropriate structure for the shoulder part of the seat belt [22]. A strap located at the second belt section works to engage the second belt. The belt is fastened sideways located on the sides of the back by a strap wherein the hook and loop fasteners fasten together. Moreover, the belt is slightly betrothed and selectively positioned at the desired height for proper function of the belt. A lateral skull support system functions to reduce the chances of injury from a side impact of the vehicle.

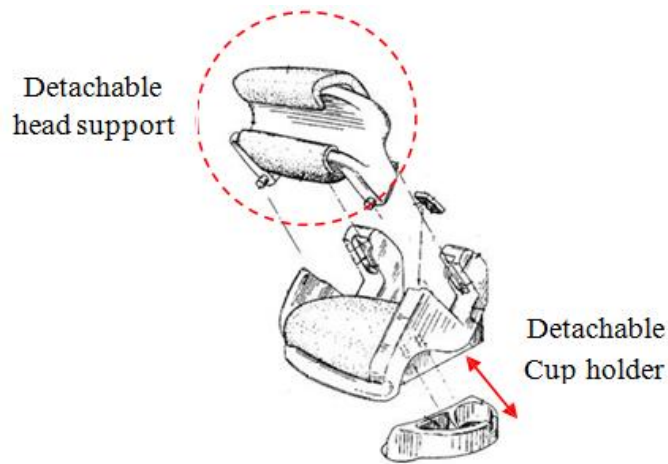


Fig. 15. Proposed design of child booster seat by James M. Kain [21]

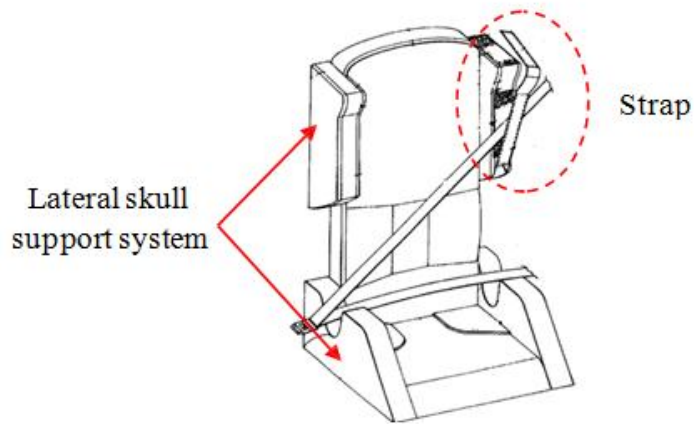


Fig. 16. Proposed design of child booster seat by Stephen Sher [22]

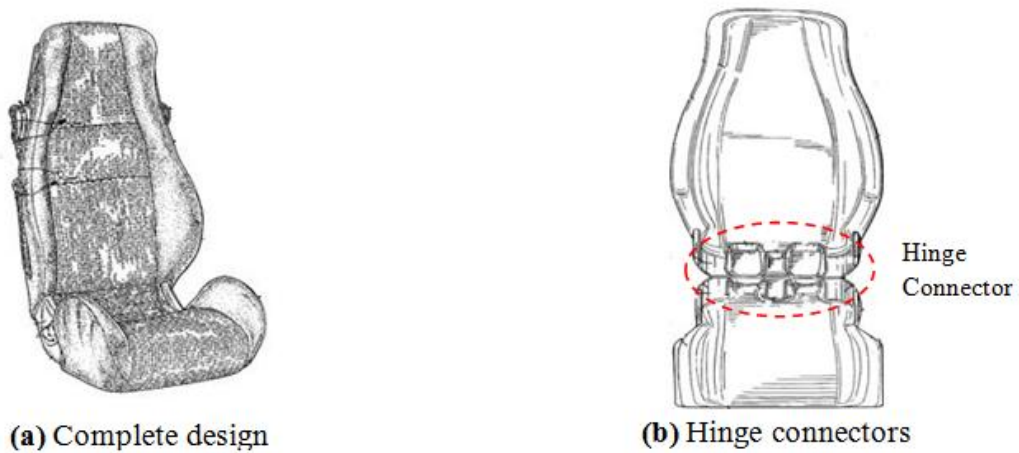


Fig. 17. Proposed design of child booster seat by Michael T. Kane et al. [23]

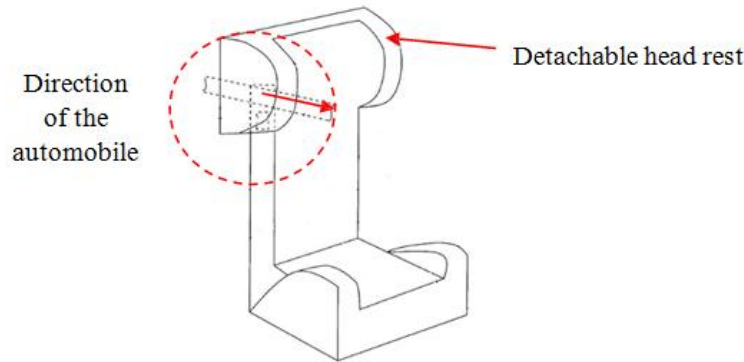


Fig. 18. Proposed design of child booster seat by Matthew H. Silverman [24]

3.6 Year 1998

The complete design as seen in Fig. 17 (a) is invented by Michael T. Kane et al. with patent number 5 845 967 and published in 1998. The inventor claimed that the molded booster seat was divided into an upper back and lower seat portion in which both were connected to an internal hinge as depicted in Fig. 17 (b) [23]. They were pivoted towards each other to form a rigid body, plurality of mortise and tendon joints. Apart from that, the invention of the booster seat also comprises of an adjustable belt position that can adapt to the various ranges of the size of the children who will be fitted into the booster seat [23].

Fig. 18 portrays the invention from the inventor known as Matthew H. Silverman with patent number 5 829 834 and published in 1998. The inventor claims that booster seat effectively assimilates the shoulder belt of a vehicle into the structure of the booster seat [24]. The combination is complete by headrests that are detachable at their lower end. To add, the belt is

netted between the headrest and the body of the booster seat in order for the belt to naturally shutter across the seat of the occupant [24]. Hence, the objective of the invention is to stipulate the improved child seat booster.

3.7 Year 2002

The design as seen in Fig. 19 was invented William R. Gibson et al, with patent number 2002/ 0033632 A1 and was published in 2002. The inventor claimed that the child car seat includes a structural seat back and a vehicle shoulder belt receiving a first hook attached to the seat back as showed at the Fig. 17 (b) [25]. The first hook substantially encloses through a first slot, where it extends from the front to the back. The first hook includes two hook members which are spaced apart from each other by a first gap which is bigger than the thickness of the webbing. It is able to engage with the first through the slot. The second hook member is placed apart from the first hook member and has a second attached portion rigidly attached to the first side portion.

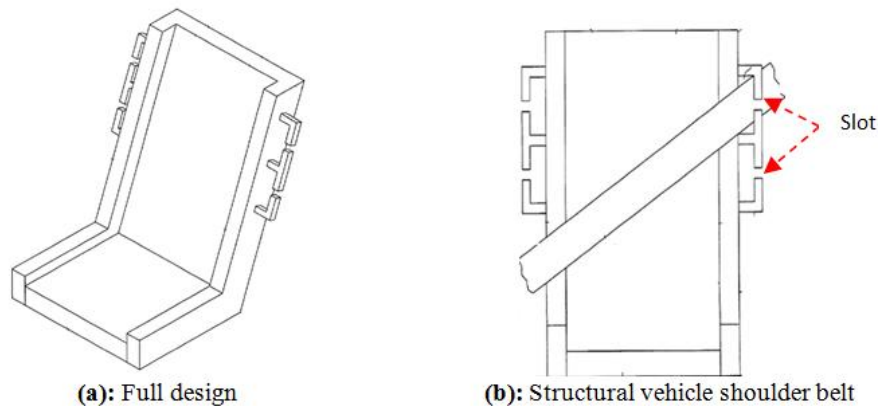


Fig. 19. Proposed design of child booster seat by William R. Gibson et al. [25]

3.8 Year 2003

The design as seen in Fig. 20 was invented by Ronald M. Asbach et al. with patent number 6,623,074 B2 and published in 2003. The inventor claimed that the design included an adjustable head support, body support, harness, or any combination thereof [26]. It had a latching mechanism together with an upper portion of the vehicle seat to a seatback. It provided a mechanical coupling between the upper portion and the seat body [26]. The mechanical coupling allowed vertical adjustment of the upper portion, which could be moved to provide an adjustable headrest for the vehicle seat. This included the side bolsters and harness guides together with an attached seat harness and/or auxiliary seat harness. It is configured as a child's car seat which may be used as either a forward facing car seat with attached harness or a belt positioning booster seat.

and winged or forward protruding surfaces that extend the length of the back surface and give support to the child [28]. Armrests are located on both sides of the seat which attach to the main seat fold pivot [28].

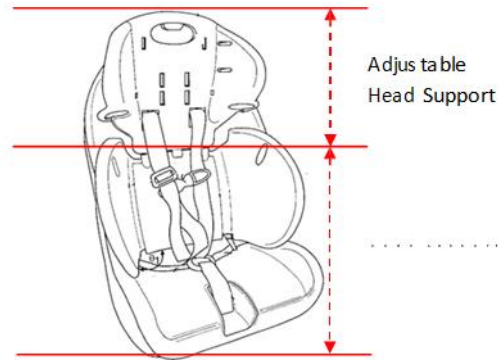


Fig. 20. Proposed design of child booster seat by Ronald M. Asbach et al. [26]

3.9 Year 2005

The design seen in Fig. 21 was invented by David Hall and Richard Bourbonnais, with patent number 2005/0189806 A1 and was published in 2005. The inventor claimed that the main objective of the invention was to provide a child booster seat having an angularly adjustable back part and a vertically adjustable headrest [27]. The seat part describes the seating surfaces and the back portion defines an elongated hollow opening towards the top surface. Meanwhile, the rear part describes an extended slot in communication with elongated cavity.

3.10 Year 2006

The design seen in Fig. 23 was invented by Derick J. Barker, with patent number 7 097 245 B2 and was published in 2006. The inventor claimed that the vehicle child seat comprises of a seat module that is able to dismount and attach to a base module and organize between the rear facing and forward facing arrangements [29]. The base module contains a telescopic and pivotable support leg and headrest components. The inventor preferred that the head rest elements including the head rest body hinge fixed at the base module.

Fig. 22 portrays the invention from the inventor known as Paul K. Meeker and William R. Gibson with patent number 6 908 151 B2 and was published in 2005. The inventor claimed that the design is more to an adjustable seat back and belt positioning of the booster car seat that can be folded compactly for easy transportation [28]. It is a molded plastic seat with a back and a seating surface. These surfaces have adjacent side walls that help protect the child occupant. The booster seat positions the auto belts to properly restrain the child. The shoulder belt and the lap belt are fairly important. The fixed part of the back assembly is coupled to the seat component of the restraint just above the seating surface and directly behind the lap belt recesses. The fixed back is constructed with all areas parallel to a central axis or spine of the back. The surfaces that comprise the fixed back outer contour consist of a generally flat back surface

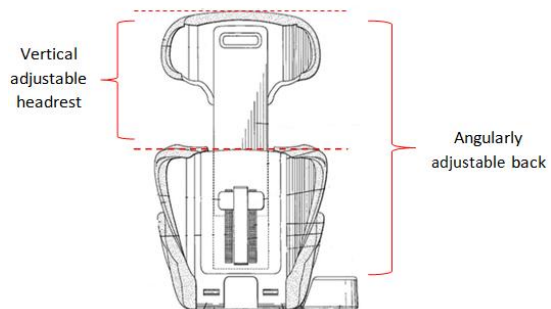


Fig. 21. Proposed design of child booster seat by David Hall and Richard Bourbonnais [27]

Fig. 24 portrays the invention from the inventor known as William et al with patent number 7 066 536 B2 and was published in 2006. The inventor

claimed that an adjustable booster seat comprise a removable back rest, a seat base, and the arm rest [30]. Moreover, the height of the back rest and the depth of the seat base can be controlled and adjusted. The backrest and the seat base was connected in order to prevent the unintentional separation and also provided a zero hassle intuitive separation when needed. Further, the belt handle operated in both modes for example at seat belt free mode or at seat locking mode [30].

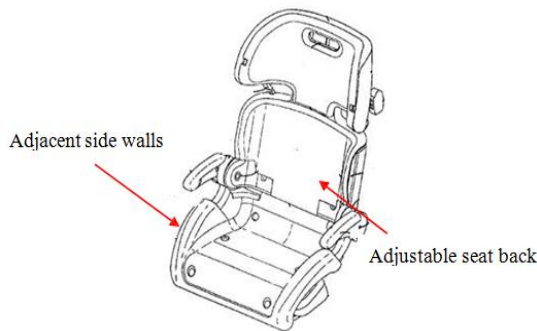


Fig. 22. Proposed design of child booster seat by Paul K. Meeker and William R. Gibson [28]

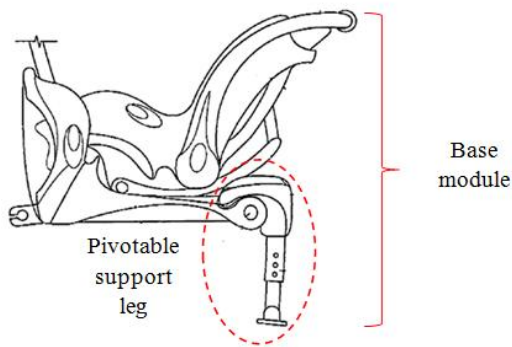


Fig. 23. Proposed design of child booster seat by Derick J. Barker [29]

3.11 Year 2007

The design seen in Fig. 25 was invented by Thomas Charles Baloga and Adrian Simms, with patent number 7 300 113 B2 and was published in 2007. The inventor claimed that the main objective of the invention was to offer a child booster seat that delivered booster safeguard to the seat occupant [31]. Further, the other purpose of this invention was to provide a safe attachment of the booster seat. Other than

that, the booster seat consisted of a seat bottom which was supported on the upper surface of a vehicle seat [31]. The first and second fasteners are carried by the adjacent first and second sides of the seat in order to locked the seat bottom to the upper surfaces of the vehicle seat by using vehicle belt.

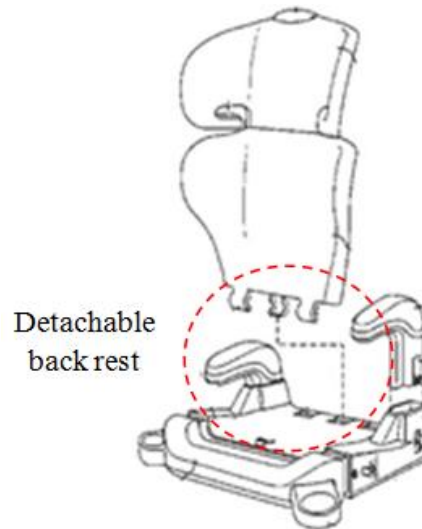


Fig. 24. Proposed design of child booster seat by William et al. [30]



Fig. 25. Proposed design of child booster seat by Thomas Charles Baloga and Adrian Simms [31]

3.12 Year 2008

The design as seen in Fig. 26 was invented by David Clement et al. bearing the patent number

the 2008/0169692A1 and was published in 2008 [32]. The inventor claimed that the invention imparts an adjustable child restraint device and was named as the juvenile safety seat. The idea of this invention is similar with the invention of previous years. In which, the main intention is to deliver a booster seat with safety or protection to the child's body. Similarly, this invention has a pair of side guards at the top and bottom end wherein each is axially joined about an axis to the backrest. Moreover, the movable gap between a closed position and the open position particularly bottom of the side guards will stay substantively constant. The curved symbol shows the positioned of the side guard's movement.

3.13 Year 2010

The complete design as seen in Fig. 27 was invented by Sanjeev Kumar Singh with patent number 2010/0033000 A1 and was published in 2010. The inventor claimed that the arm rest of the booster seat can be adjusted to the desired reclined positions controlled by an adjustable mechanism [33]. Further, the latching system locks the seat back into the seat member in an operative coordination.

3.14 Year 2011

The complete design as seen in Fig. 28 was invented by James M. F. Hutchinson et al. with patent number 7 862 117 B2 and was published in 2011. The inventor claimed that the invention contained a head rest and harness support, with their functions being to properly hold the position of the harness [34]. Similar to the invention in the subsequent year, the head rest was adjustable and movable along the curved

track in order to offer a horizontal clearance when it is in a completely raised position. Moreover, the belt is confined in an adjustment lock and tailed around a fixed guide bar at the top of the car seat frame [34]. It moves downwards through a guide member that leads the belt across an opening in the seat back.

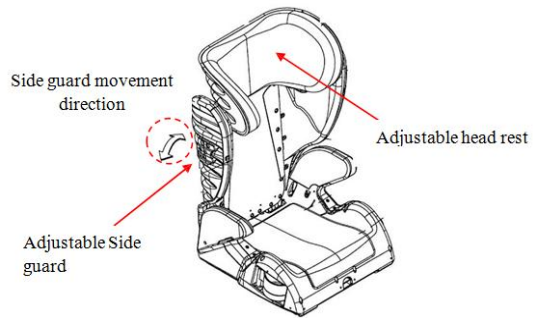


Fig. 26. Proposed design of child booster seat by David Clement et al. [32]

3.15 Year 2012

The complete design as seen in Fig. 29 was invented by Patrick M. Glance with patent number 8 182 034 B2 and was published in 2012. The inventor claimed that the child booster was portable and that it could be folded into the vehicle. The collapsible car booster seat includes a foldable seat member wherein the removable arm rest on the vehicle seat [35]. Besides that, the arm rests can be extended upwards from opposing sides of the seat member. The seat base may be lifted up to the deployed position and folded for storage. Furthermore, the arm rest have a deployed position in which the legs can be lengthened vertically from the seat base and the arm rest extended forward [35].

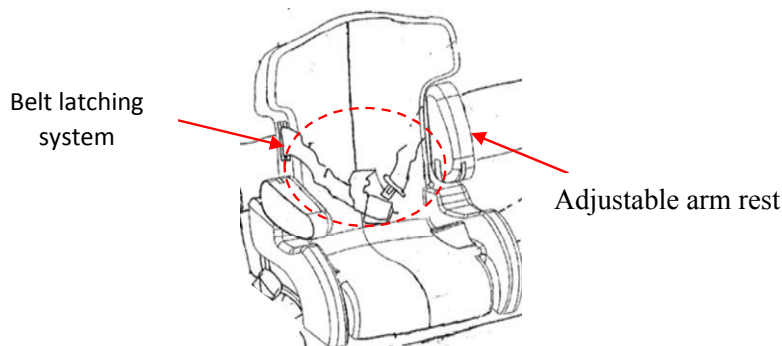


Fig. 27. Proposed design of child booster seat by Sanjeev Kumar Singh [33]

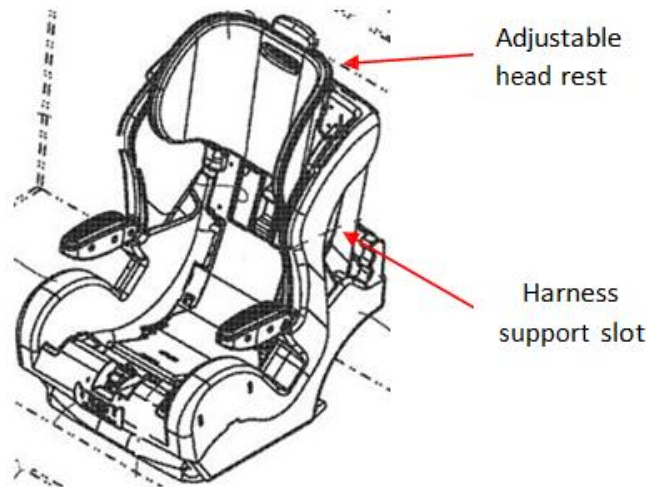


Fig. 28. Proposed design of child booster seat by James M. F. Hutchinson et al. [34]

3.16 Year 2013

The complete design as seen in Fig. 30 was invented by Dave Szakelyhidi et.al. with patent number 2013/ 0088057 and was published in 2013. The inventor claimed that the child restraint system which offered an automated installation comprised of automated feedback and control of seat angle, belt latching and close fitting, and corroboration of the right installation [36]. Additionally, this invention used a sensor to supervise the base angle of the booster seat that was relative to the level and confirmation of proper latching. The process of operation and confirmation of the installation was controlled via buttons or other tactical input and it communicated to the user through an electronic visual display and audible means [36].

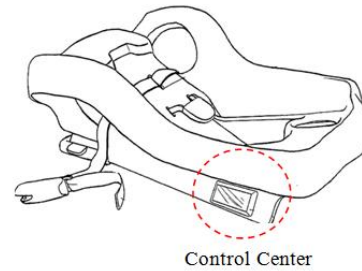


Fig. 30. Proposed design of child booster seat by Dave Szakelyhidi et al. [36]

3.17 Year 2014

The complete design as seen in Fig. 31 was invented by Grainne Kelly with patent number 8 678 499 B2 and was published in 2014. The inventor claimed that the invention provided a base which contained of at least one inflatable member in which the child will sit above [37]. Further, the harness is fitted on either side at the front part of the base to preserve the base. Slots are located at the lateral sides of the cover to permit way to inflate or deflate the car booster seat.

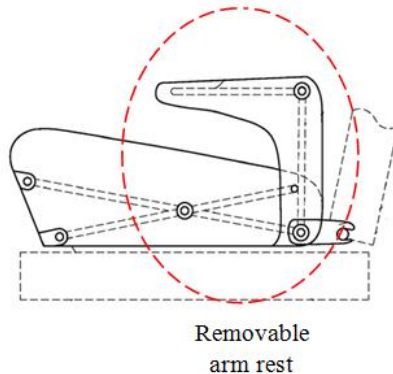


Fig. 29. Proposed design of child booster seat by Patrick M. Glance [35]

3.18 Year 2015

The complete design as seen in Fig. 32 was invented by Richard P. Juchniewiez et al. with patent number 2015/ 0091348 A1 and was published in 2015. The inventor claimed that the booster seat comprised of a seat base mounted

to the seat of a vehicle. The child will be supported by the seat base and the belt tightness system assimilated into the seat base [38]. The belt tightness was designed to accept a belt that connects the seat base to the seat vehicle. To add, the child seat also consists of a controller operatively associated to the belt tightness system and organized to mechanically actuate the belt system [38].

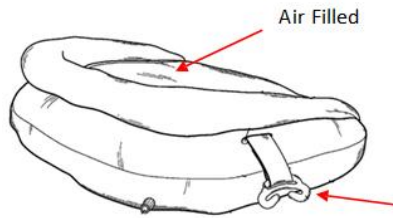


Fig. 31. Proposed inflatable car booster seat by Grainne Kelly [37]

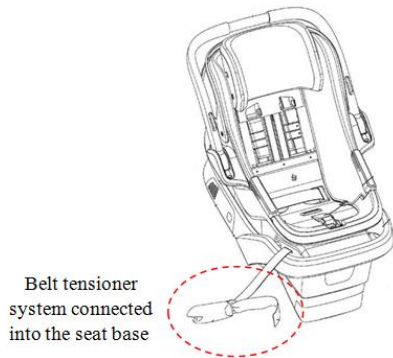


Fig. 32. Proposed design of child booster seat by Richard P. Juchniewicz et al. [38]

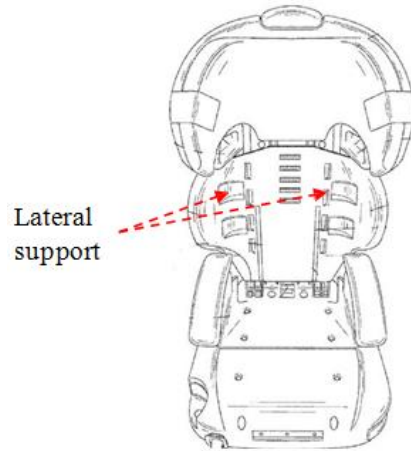


Fig. 33. Proposed design of child booster seat by Thomas Jake Mitchell [39]

3.19 Year 2017

The complete design as seen in Fig. 33 was invented by Thomas Jake Mitchell with patent number 2017/ 0282758 and was published in 2017. The inventor claimed that the child booster seat came together with a removable belt positioner [39]. The child restraint system comprised of a seat back that could be separated from the seat base. The base contained a primary seat base and a detachable seat base. It could also be used without the primary seat and acted as a booster seat for a child. The car booster seat contained a lateral support to keep the child in a secured position within the outer boundaries during acceleration and deceleration. Additionally, the arm rest could also be adjusted to the seat like the removable seat base [39].

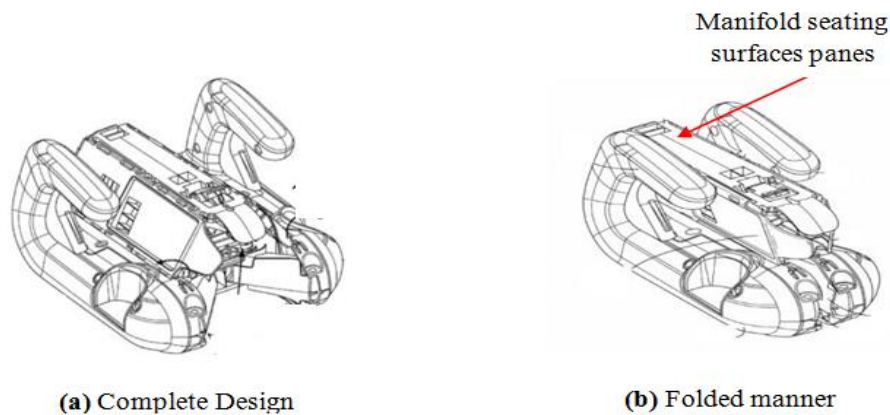


Fig. 34. Proposed design of child booster seat by Taylor Daniel Genoway et al. [40]

3.20 Year 2018

The complete design as seen in Fig. 34 was invented by Taylor Daniel Genoway et al. with patent number US 2018/ 0050615 and was published in 2018. The inventor claimed that the booster seat can be folded from an in-use formation to a collapsed configuration [40]. This was designed to enhance the portability function of the booster seat base. Furthermore, the booster seat base contained manifold seating surface panes that could pivoted couple to each other in which it permitted the booster seat base to fold [40]. This invention also included tab members that could be interleaved into the tab accepting holes of the booster seat back [40].

4. SUMMARY OF DESIGN ON CAR BOOSTER SEATS

From the literature survey analysed above from years 1988 to 2018, several important points may be appreciated pertaining to the design and development of car booster seats for children. They are as follow:

- Ergonomics design on car booster seats for children were implemented from 1988 till present;
- At an earlier time, the primary invention focused only on restraining children from strolling around in the car. Design factors such as comfort and multi features on the car booster seats were not implemented. Apart from this, car booster seats appeared to be bulky in their design: they were more rectangular shaped;
- The design pattern of booster seats for vehicle are mostly similar whereby they mainly consist of a seat base, seat back, arm rest and latching safety system;
- Subsequently, the safeguards were designed and attached together as protection mechanisms for the occupant;
- Foldability was eventually introduced by Paul K. Meeker in 2005 where the seat base and seat back could be coupled and decoupled by internal hinges or connectors. The configuration can be changed from an in-use formation to a collapsed configuration and vice versa;
- The idea of car seats being transformed into car booster seats was introduced in 2017;
- Electronic features were incorporated into car booster seats in 2012. Some of the

electronic features considered were automated feedback and motorised control of seat angles, belt latching and tightness system and verification system of correct installation of the car booster seat; and

- Features that ensure the infant is comfortable such as the correct position of shoulder and lap belt and adjustable to desired height are common and necessary.

5. PROPOSE FUTURE RESEARCH ON CHILD CAR BOOSTER SEATS

Based on the works reviewed above, several points may be highlighted to allow for new research pathways into car booster seats for children. They are:

- Fusing electronic components into car booster seats. These electronic features may include but are not limited to: heating/cooling mechanisms on the back and the base of the seat, lighting devices to illuminate important areas of the seat, machines to heat child milk and etc.;
- The artistic looks of the car booster seat may be improved in terms of its overall design. For example, there could be a “catchy” design of the seat cover, (i.e. example of catchy design: seat cover made of materials that portrays the interest of boys/ girls; example: boys loves robots, girls love dolls). This is particularly to attract the interest of the child to sit in the car booster seat during the operation of the vehicle;
- Incorporating smart materials such as memory foam into the child booster seat;
- Curtain airbags could be directly installed into the car booster seat for added protection for the child in the event of a car accident;
- To introduce a car booster seat that “grows old” with the users; (i.e. grows old means child booster seat is fully adjustable when the body dimension of the user changes with respect to time); and
- To design and develop a car booster seat with multipurpose usages; (i.e. multipurpose usage includes car booster seat that can be attached to an existing baby stroller; attached to a shopping cart trolley; attach to a typical adult dining chair and etc.).

6. PROPOSED STATE OF THE ART CAR BOOSTER SEAT

As observed earlier, the existing designs of car booster seats for children are far from perfect. The functions offered in any one car booster seat do not accommodate the desire and needs of everyone. Nonetheless, there are some potential ways to enhance and upgrade the design of the existing car booster seat. Supposing that a child is around 4 to 5 years old, Fig. 35 summarizes the proposed car booster seats for various applications.

The body temperature of the child is the essential to ensure that children continuously feel comfortable on the booster seat. Heating and cooling elements located in the child booster seat must be introduced in order to resolve this issue. This invention is capable of ensuring that the body of the child is continuously warm or cool when needed. Children are known to have sensitive skin and easily developed rashes or blisters. Many factors can contribute to this problem, including when children have been seated for too long on the car booster seat. Therefore, the cooling elements will ensure that children stay comfortable especially during hot days. Vice versa, the heating elements

ensure the children stay warm during cold weather.

Mostly, the available designs in the marketplace are plain designs with dull or basic colours. Children are easily attracted and therefore enjoy attractive designs. The next proposed art is the invention of car booster seat with an artistic look on the overall design of the child booster seat. This will capture the interest of children and keep them on the booster seat. Hence allowing for a hassle-free journey.

This invention also offers an adjustable height by using the 'slight & slot' mechanism. This mechanism is operated by manual sliding the compartments into its slot until they reach the desired height. This mechanism also can be used as storage compartments that can store the necessities such as extra diapers, milk formula, extra clothes, candy, etc.

Memory foam is categorized as a 'smart material' owing to its ability to take contour of the body shape and remain so until the person or object is removed. Further, memory foam is denser than normal foam, making it very comfortable for the users. Therefore, in this invention, memory foam will be applied to the child booster seat instead of normal foam.

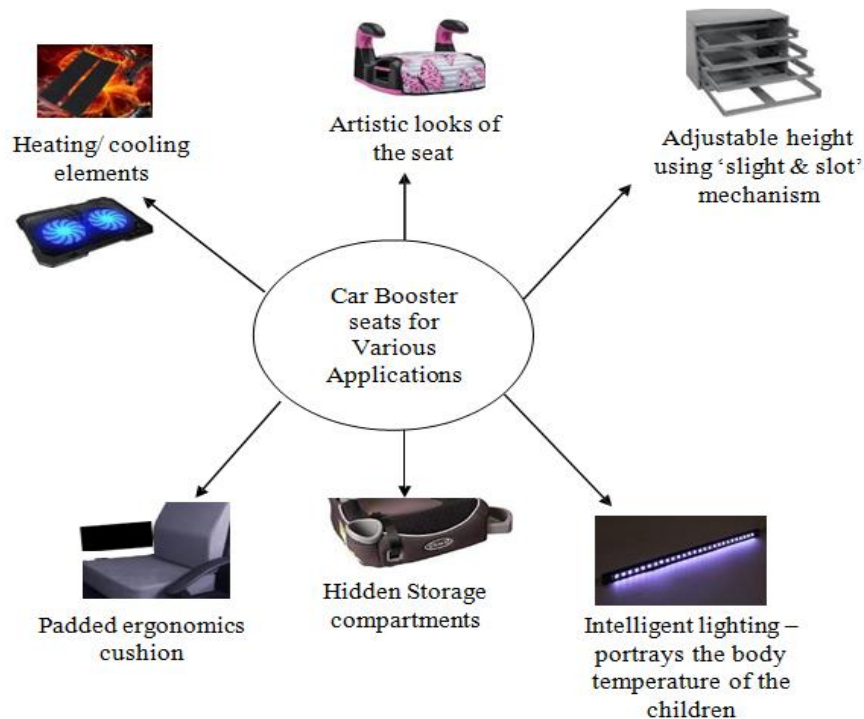


Fig. 35. Proposed state of the art features of child car booster seat

Additionally, ergonomics is essential to any design and development of children's goods. This invention delivers an ergonomics padded cushion that can be removed and washed. For example, the padded cushion could be taken out and washed in the event of a spill of any drink or vomit. This allows for the booster seat to remain hygienic and safe for children. Further, the padded cushion can be used for both sides. For example, the cushion can still be used like usual if the other side is dirty or wet, by turning it upside down.

Generally, the current boosters seat offered in the market do not include any lighting mechanisms. This invention comprises of an intelligent light located at outer side of the arm rest. The main purpose of this light is to illuminate the important areas in the dark. The booster seat also consist of a sensor to indicate the body temperature of the child and this remains displayed through the intelligent light. There are 3 colors that are able to show the temperature of the child such as green signaling that the child's temperature is normal, orange color meaning the child's temperature is beginning to increase, and red signaling the temperature of the child is above normal (37.5 degree Celsius).

7. CONCLUSION

By subcontracting the design and manufacturing of the attachments, this unique idea could be developed larger into a more efficient product, more rapidly, on a larger scale. The potential of its various types of attachments would be limitless. Finally, taking into consideration the design and safety factors of the current market trend car booster seats for children, the writers also propose possible state of the art car booster seats for various applications.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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