

Conceptual Framework for the Design of a Child Motorcycle Safety Seat

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ABSTRACT—Motorcycles are a common mode of transport in Malaysia where families with children can be common seen riding together. However a child riding pillion on underbone motorcycles are not safely protected from falling down from the motorcycle apart from holding onto the adult in front. The current feature in an underbone motorcycle seat does not provide or lack the necessary protection for the child pillion riders. The current seat requires a systematic framework in order to design and develop a safety motorcycle backrest seat for Malaysian child pillion riders of underbone type motorcycles. Therefore the main objective of this paper is to propose a conceptual framework to showcase the conceptual design and development of a child friendly motorcycle seat. In order to design and develop our safety motorcycle backrest seat for child pillion riders, a leading International Automotive Consultancy's (IAC) New Product Introduction (NPI) process and subsequent IAC Design & Development Process was adopted and adapted to be able to properly design, develop, test and produce a robust prototype seat. The main IAC NPI will be abbreviated from the kick off until the prototype release milestone. The IAC NPI is then divided to 4 main phases starting from the initiating five concepts and choosing the best concept; designing and developing the chosen concept; building the first prototype test the design; validating the design and releasing the final prototype.

Keywords—Children, safety, motorcycles, ASEAN, Malaysia, design, framework

1. INTRODUCTION

South East Asian Nations (ASEAN) have been experiencing rapid economic growth which in turn has seen a rapid growth in its population and its people's ability to own motorised vehicles. This has directly caused child road traffic accidents and injuries to the forefront of public health issue. Child occupant safety has now become a prominent issue of child safety in ASEAN countries especially nations such Malaysia [1][2].

Motorcycle is a normal mode of transport in Malaysia accounting for 43% of the total vehicles on Malaysian roads currently [3]. The category of most commonly used motorcycles in Malaysia is the Underbone motorcycle category or the "Kapcai" [4]. With this high amount of motorcycles on the road, for many families in Malaysia, the motorcycle is their main mode transport. Watson et al describes a pillion rider as "a passenger on a motorcycle. A pillion passenger should be positioned directly behind the rider, facing forward on a registered seat for a pillion passenger [5][6]. In middle income nations especially in developing Asian nations, it is very common for a child pillion rider to be seen riding a motorcycle with an adult in front. Parents may begin to carry their children on the motorcycle at a very young age. This is done by either seating the child in front or behind the rider [6][7].

A major issue facing motorcycle users in ASEAN nations especially in Malaysia is the high rate of accidents involving motorcycle users. During an accidents, there are high probabilities that deaths will also happen. When a child rides pillion, the child normally holds on to the adult rider really tight to avoid falling down and also to balance themselves [6][7].

Society has a responsibility in ensuring that children are protected especially from road traffic accidents and injuries as children are categorised as a vulnerable group in traffic. Road traffic injuries (RTIs) is a leading factor of disability, morbidity and mortality. By the year 2020, globally, it is predicted that road traffic injuries could be one third of all major causes morbidity and mortality [8][9]. As mentioned above, injury prevention is not solely on the shoulders of parents or teachers. Enforcement of the rules by the authorities is always the short term solution to ensure child pillion riders' safety. Instead, a technological intervention is needed [10][11]. Interventions also has to be initiated from the highest policy-making level and be translated across all levels of civil and private sectors, right down to daily practices [11].

The joint UNICEF-WHO 'World Report on Child Injury Prevention' report recommends a wide range approach in tackling child injury prevention. The report among other things recommends that governments are responsible for enacting and implementing multipronged strategies for child injury prevention. Most importantly though, the joint report also recommends product modification to ensure child safety and injury prevention as a priority [12].



Figure 1:Example of pillion riders without adequate protection

The current feature in an underbone motorcycle seat does not provide or lack the necessary protection for child pillion riders. A child would struggle to hold on and balance himself/ herself properly on the motorcycle seat as the motorcycle moves along. The child pillion rider's legs are also usually not able to reach the adult foot pedal properly and is susceptible to hit the hot exhaust pipe of the motorcycle where the child could suffer serious burns. As shown in Figure 1, the child at the back is struggling to hold on to the motorcycle as it moves along. The picture above clearly shows that the current motorcycle seat does not have any safety features for a child pillion rider [7][13][14].

Engineering intervention to the underbone motorcycle is needed. This intervention will need to specifically address the prevention of injuries typically sustained by child pillion riders on underbone motorcycles. A device or intervention that will be able to protect the chest, neck, foot and ankle, backbone of the child will be designed and developed. This backrest should be able to provide a form of protection to young pillion riders [7][12].

Motorcycle Original Equipment Manufacturers (OEMs) are classified as automotive OEMs as well. When creating a new product or design, automotive OEMs are guided by a process called the New Product Introduction (NPI). The NPI process is widely used across in many industries when creating new products or coming up with a new design. In the automotive context, the NPI is the process which a new product idea is conceived, investigated, taken through the design process, manufactured, marketed and serviced. The NPI model is the master plan by which the organisations guides itself for its product innovation and development. The NPI in turn is the part of the Advanced Product Quality Planning (APQP) process which is used by many major automotive companies when they are developing their new products and models. APQP was developed in the late 1980s by a commission experts formed by Ford, General Motors and Chrysler who were the big three US Automobile manufactures at that particular time. The commission analysed automotive development and production in the major automotive countries at that time namely United States, European countries and Japan. The APQP process is described as process "to produce a product quality plan which will support development of a product or service that will satisfy the customer. In the APQP process, the product realisation process consists of 5 main

phases which are “Plan and Define Program”, “Product Design and Development”, “Process Design and Development”, “Product and Process Validation”, and “Production Launch, Feedback Assessment and Corrective Action” [15][16][17][18][19]. The APQP process as shown below in Figure 2 where the process flow is shown over a time period.

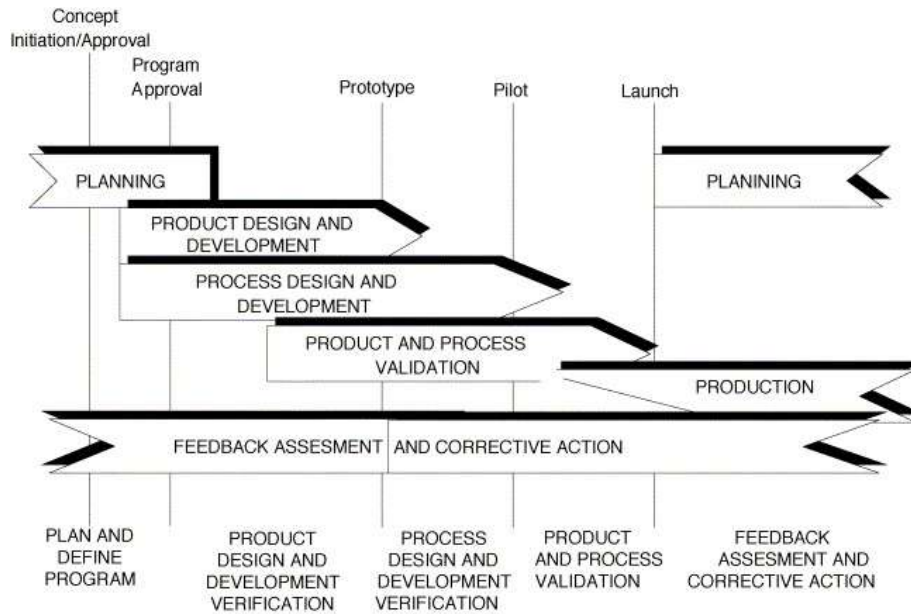


Figure 2: APQP product quality planning timing chart [13]

The authors decided to base this study on an International Automotive Consultancy’s process of work due to its proven robustness and prior success. In order to protect the copyright of the IAC, henceforth going forward, the company shall be referred to as IAC. The IAC is an automotive consultancy company that develops full scale new vehicles and parts for external and internal customers. The IAC uses its own propriety process called the New Production Introduction (NPI) for developing a complete vehicle or automotive components associated with the vehicle. The IAC NPI itself is derivative of the APQP process as shown below. The NPI provides guidelines with regards to the development process that need to be undertaken for introduction of a new product. It starts from the formation of ideas, then going through the development process and successful product launch and ends with the closure of the project. It also integrates and streamlines all the activities and resources within the company to guarantee a successful product introduction. The NPI process is intended to ensure that the product to be introduced has a robust process which will reduce mistakes and ensure that the product meets the set requirements. This process has been used by IAC over the past decades and it has been continuously improved over time. IAC has stated that the NPI is the default process for all of its Automotive Engineering Projects. The framework proposed below is a summary of the conceptual framework that will be used to design, development and testing of the seat. This framework is adapted from IAC’s NPI process [20][21].

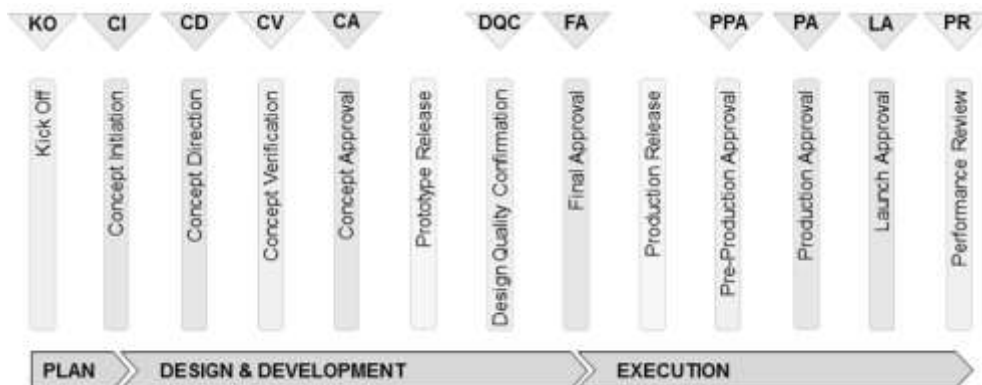


Figure 3: IAC NPI Gateway Structure [20]

The NPI process is based on the best practices developed from working with other leading vehicle manufacturers and

is controlled through gateway events which reviews the progress against pass/hold criteria, and establish actions and metrics for the next phase. The phases in Figure 3 above show gateways and milestones which will be further elaborated in the results sections [20].

A Gateway is a review of project deliverables at the set point in time as defined by the project timing plan and the IAC NPI Process in order [20]:

1. To gain acceptance that the Project has met the deliverables and objectives of the current Gateway phase
2. To establish the readiness of a project to move forward into the next Gateway phase
3. To determine the basis on whether to proceed or not to proceed to the next gateway if the project has failed to meet all set of deliverables and objectives of the particular gateway

At every gateway event, there are specific deliverables and documents which need to be completed. Those documents need to signed-off by the higher authority of the organisation and presented at the gateway event. Based from the outcome of the deliverables, a decision will then be made on whether the gateway should be approved or otherwise. If the deliverables are not met, then a decision will be made on whether these failed deliverables can be carried forward to the next gateway or the current gateway will need to be repeated at a another set point of time once all set deliverables are achieved [20].

A Milestone event is a scheduled interim review of the deliverables output of a project where a long period exists between Gateways [20].

2. OBJECTIVE

The main aim of this paper is to propose a conceptual framework to showcase the conceptual design and development of a child friendly motorcycle seat for the Malaysian market and other ASEAN markets where the underbone type motorcycles are common.

3. METHODS

In order to design and develop the safety motorcycle backrest seat for child pillion riders, we have adopted and adapted the IAC NPI and subsequent IAC Design & Development Process to form a conceptual framework in order to design, develop, test and produce a robust prototype seat. The following sections will describe in detail the IAC NPI and IAC Design and Development Process used to for our product.

4. RESULTS

IAC uses its New Product Introduction (NPI) Process as a framework for its vehicle programmes and will be utilized for the design and development of the safety motorcycle backrest seat for child pillion riders. The following section describes the NPI in more detail.

4.1 New Product Introduction (NPI)

The IAC NPI is a robust framework to manage any vehicle related project delivery ensuring the efficient integration of all the functional groups essential to the technical and commercial success of a vehicle programme. IAC's proven product development process will be used as a reference for designing the safety motorcycle backrest seat for child pillion riders. However for this project, we will only need to get the safety motorcycle backrest seat to the prototype phase, this project can therefore be aligned to 5 major gateways related to the hardware requirements/ readiness of the product as shown in the Figure 4 below.

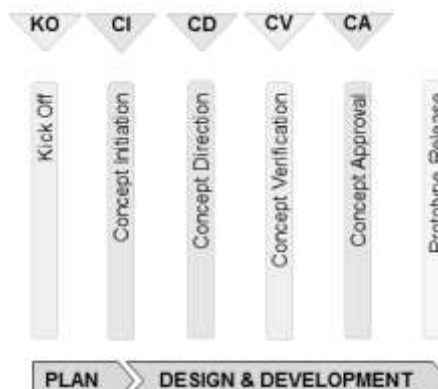


Figure 4: Proposed Gateways and Milestone for the Design & Development of the Safety Motorcycle Backrest Seat for Child Pillion Riders

The chart shown above (Figure 4) is abbreviated version of the major Gateways of Figure 3.

4.2 NPI Gateway and Milestone breakdown

The key gateways and definitions of the NPI process are listed below, followed by a summary of deliverables for the design and development of the safety motorcycle backrest seat for child pillion riders.

4.2.1 Gateway 1: Project Kick Off

In the project kick off, a review of the need of the safety motorcycle backrest seat for child pillion riders is undertaken to see the viability this need being turned into a product or project. The need of the safety motorcycle backrest seat for child pillion riders is then presented to a higher authority seeking their approval and resource to develop the need into a proper viable Project. Activities required to achieve the deliverables of the CI Gateway is then initiated [20].

4.2.2 Gateway 2: Concept Initiation)

The Concept Initiation (CI) is the start of the design of the ideas for the safety motorcycle backrest seat for child pillion riders. During this phase, a review of the product and market requirements including the business case, definition of roles and responsibilities, review of proposed project timing plan, resources requirements and funding needed up to completion of the programme. Based on this review a decision is to be made on funding/progression of the project into the next phase [20].

4.2.3 Gateway 3: Concept Direction (CD))

During this Gateway, the safety motorcycle backrest seat for child pillion riders's requirement is clearly stated from the previous gateway (CI) and a solution presented to achieve the requirements. This should cover the technical feasibility of the safety motorcycle backrest seat, bill of materials targets, project budget. The main objective of this gateway is to select and agree the direction for the project and the safety motorcycle backrest seat [20].

4.2.4 Milestone 1: Concept Verification (CV)

In concept verification, it is a milestone that has an interim report towards achieving Concept Approval. In this Milestone, a review of the results to-date from the first stage safety motorcycle backrest seat prototype build and the test, development and validation programme. A review of the actions is then undertaken to resolve the issues identified [20].

4.2.5 Gateway 4: Concept Approval (CA)

In this gateway, common approval is needed to ensure that the final safety motorcycle backrest seat meets the set requirements. The purpose of this gateway is to review the safety motorcycle backrest seat against the set goals and requirement. A review of the design, technical specification, test results to date, production feasibility, project cost against target, and possible business plan/case review to ensure the safety motorcycle backrest seat meets the set requirements so as to give approval of the final product selected and enable a decision to be made on progression of the project into prototype release milestone [20].

4.2.6 Milestone 2: Prototype Release (PR)

Prototype release is the final milestone of the design and development of the safety motorcycle backrest seat . An option that is also available is virtual prototyping. These days, in order to save costs, virtual prototyping is more commonly used alternative to rapid prototyping to validate products. The convergence of technologies such as simulation, computer aided design (CAD) and virtual reality have enabled the accessibility of low cost, user-friendly virtual prototyping systems [22][23][24].

5. DISCUSSION

The design, development, fabrication and testing of the safety backrest for the children pillion riders will be based on the process chart below from IAC which is the normal process undertaken by IAC for all of the automotive design work [20].

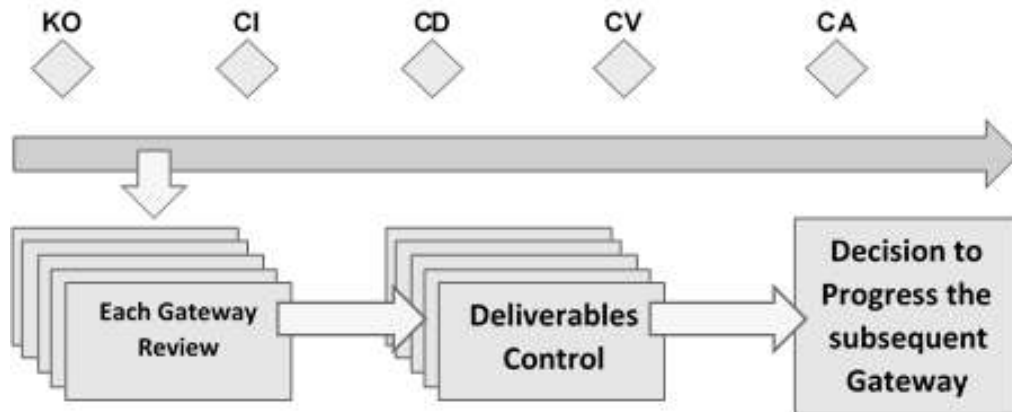


Figure 5: Process Chart for the Design & Development of Safety Motorcycle Backrest Seat for Child Pillion Riders

The Figure 5 above summarises that after each gateway, there has to be a gateway review for a review of the project deliverables and a decision will be taken whether to move forward to the next gateway. This is further expanded in Figure 6 below.

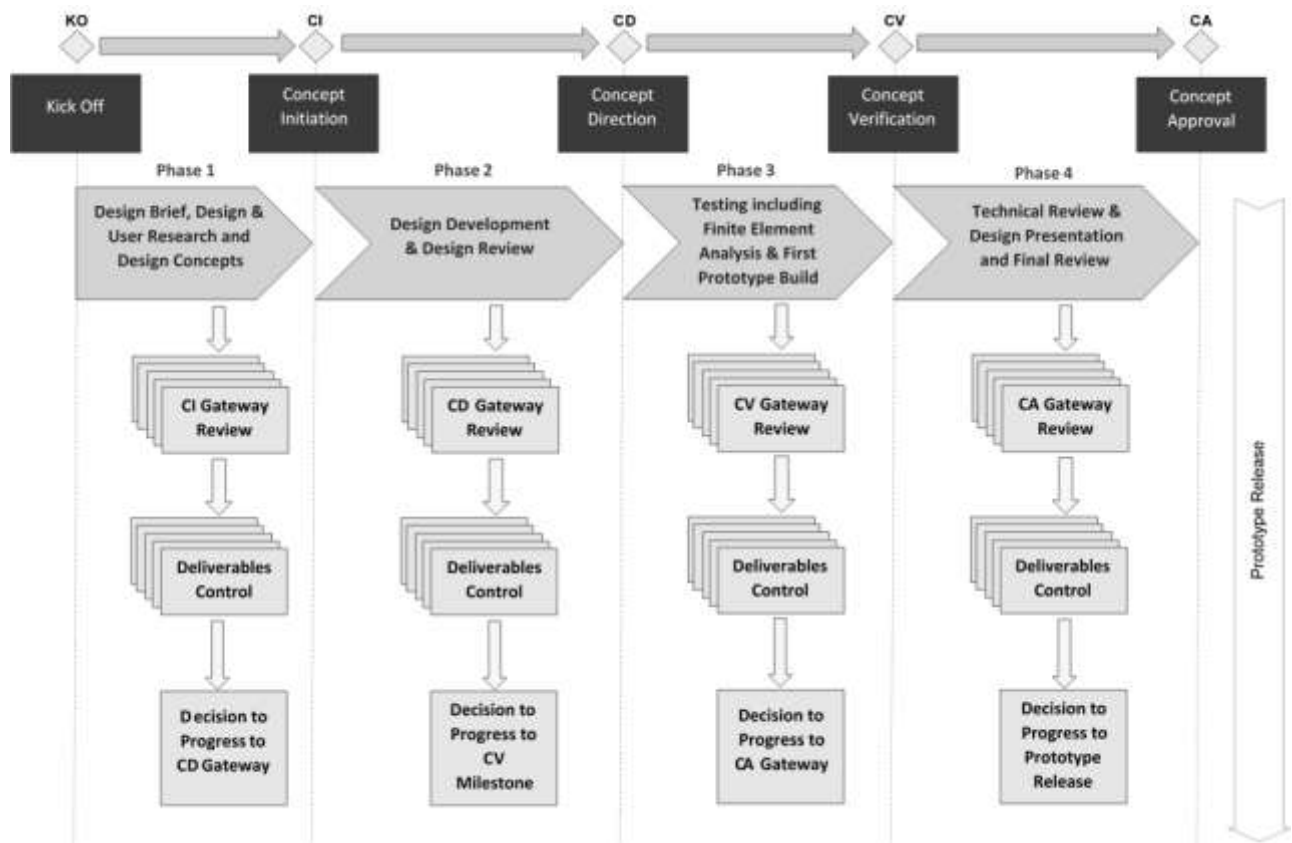


Figure 6: Expanded Process Chart for the Design & Development of Safety Motorcycle Backrest Seat for Child Pillion Riders

This study will be based on the IAC Design & Development Process which in turn is based on the IAC NPI currently being used in IAC. The IAC Design & Development Process is meant to provide the guideline with regards to the design and development process that needs to be undertaken for introduction of a new automotive product. The chart shown above is from the start of a concept until the final prototype release.

Since the safety motorcycle backrest seat for child pillion riders will be taken until the Prototype Release (Engineering Prototype (EP)) stage only, this research will be based on the modified chart below to reflect that that the safety motorcycle backrest seat is only till the prototype stage. The project can therefore be aligned to 4 major phases related to the hardware requirements/ readiness of the product.

From Figure 6, the design and development process are summarised in the 4 phases as shown in Figure 7 below.

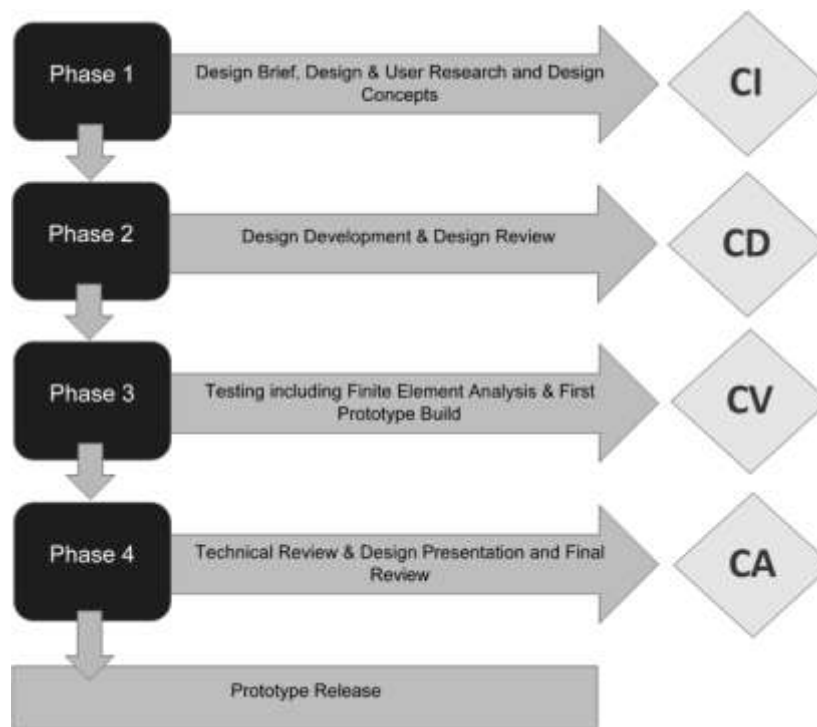


Figure 7: Phases of Design & Development of Safety Motorcycle Backrest Seat for Child Pillion Riders

The main phases of the design and development of the safety motorcycle backrest seat will be as follows:

Phase 1: Design Brief, Design & User Research and Design Concepts

Phase 2: Design Development & Design Review

Phase 3: Testing including Finite Element Analysis & Prototype Build

Phase 4: Technical Review & Design Presentation and Final Review

5.1 Phase 1: Design Brief, Design & User Research and Design Concepts

Phase 1 starts from the Project Kick Off till the CI gateway. During Phase 1, a review of the safety motorcycle backrest seat and user requirements are carried out to identify the safety motorcycle backrest seat's target objective. Once this has been identified, then the team's roles and responsibilities are defined in order to clearly map out each and everyone's roles in the team. A review of the proposed project timing plan is then finalised and agreed during this phase. Also possible resource requirements and funding if needed is identified during this phase. The most important activity during this phase is the development of safety motorcycle backrest seat concept designs based on user research and needs are done. For the safety motorcycle backrest seat, there will be 5 concept design that will be proposed and evaluated [20].

5.2 Phase 2: Design Development & Design Review

Phase 2 starts from the CI Gateway till the CD gateway. During this phase, the most suitable safety motorcycle backrest seat concept is chosen and design and development is started based on the best suitable concept. During this phase there will be constant review of the design undertaken so as to ensure that the design does not stray from the set objective. The technical & process intent is also laid out where the technical specification is set together with packaging suitability and feasibility of the product to be manufactured. The cost target of the safety motorcycle backrest seat is also set to ensure that the product meets the set requirements. All of the above are done so as to give approval of the final product selected and enable a decision to be made on progression of the project into the next phase [20].

5.3 Phase 3: Testing including Finite Element Analysis, Prototype Build

Phase 3 starts from the CD Gateway till the CV milestone. During this phase the first safety motorcycle backrest seat prototype is built and testing is carried out based on the set requirements. The testing will be carried out using finite

element analysis and also physical testing. For the FEA process, two major tests are carried out; the simulated crash analysis and stress analysis. The purpose of the crash simulation is to ensure major structural components and joints are optimised to meet crash-worthiness of crash requirements. The stress analysis is carried out to analysis the stiffness and durability load cases to predict seat structural performance. The progress of the testing, and validation plan is constantly monitored and updated to achieve Design Sign-Off and Finalisation. A review of the actions that have been undertaken above is meant to resolve the issues identified throughout this stage [20].

5.4 Phase 4: Technical Review & Design Presentation and Final Review

Phase 4 starts from the CV Milestone till the CA gateway. A project review is undertaken where the achievement and lessons learnt is recorded. A review of feedback from the selected users is taken if possible. During this phase, all validation activities have to be completed and hence the project is complete and closed. Once the project is complete, the Prototype Release is done [20].

6. SUMMARY

Malaysia has a growing motorcycle population with more than 43% of the vehicles on the road being motorcycles with the underbone motorcycle being the most common on the road [25]. Due to low cost to own a motorcycles, many families tend use motorcycles for their daily commute. It is not uncommon to see a child riding motorcycles with an adult in the front. A pressing public health issue facing Malaysia is the safety of child pillion riders on underbone motorcycles. When a child rides pillion on motorcycles, they end having to hold and hug tightly the adult in front in order to balance themselves and keep from falling down. This due to the current motorcycle seats in the market do not provide or lack the necessary protection for the child pillion riders. The current seat requires a systematic framework in order to design and develop a safety motorcycle backrest seatfor Malaysian child pillion riders of underbone type motorcycles

An engineering intervention is needed to tackle this problem of child pillion safety on motorcycles. Hence a child safety motorcycle backrest seat will be designed and developed to help to alleviate this problem. The design and development process of the safety motorcycle backrest seatwill be done according to the IAC New Product Introduction (NPI) Process.

This paper highlights the conceptual framework proposed to achieve the conceptual design and development of a safety motorcycle backrest seat for children. Due to the safety motorcycle backrest seat being taken to the prototype release stage, the IAC NPI will be abbreviated to the Prototype Release Milestone, where we start from the Kick-Off Gateway. The IAC NPI is then divided to 4 main phases starting from the kick off, initiating five concepts, choosing the best concept, designing and developing the chosen concept, building the first prototype test the design, validating the design and releasing the final prototype. Once the final prototype is done, the project would be complete.

7. CONCLUSION

This paper was written to highlight the conceptual framework needed for a conceptual design and development of a safety motorcycle backrest seat for children. The authors will adapt the IAC NPI and IAC Design and Development process for the design of the safety motorcycle backrest seat. The IAC NPI is a widely used process in the automotive industry. The authors have narrowed down the process down to 4 major phases starting from the kick off, initiating five concepts, choosing the best concept, designing and developing the chosen concept, building the first prototype test the design, validating the design and releasing the final prototype.

8. FUNDING

This research is supported by the Ministry of Education Malaysia (MOE) Fundamental Research Grant Scheme (FRGS), Grant No: FRGS/2/2013/SKK10/UPM/02/9.

9. ACKNOWLEDGEMENT

The authors are thankful to the Department of Environmental Health and Safety of the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, for their support and guidance in preparing this article. The contents of this article are solely the responsibility of the authors.

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