

Overview of pedestrian analysis setup and post-processing using the Oasys LS-DYNA Environment with a focus on new features

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1 Introduction

The Oasys LS-DYNA Environment provides a comprehensive solution across the whole LS-DYNA workflow.

One aspect of that workflow in automotive engineering is pedestrian protection. Pedestrian protection is important to the design and development of the front end of vehicles. The various protocols, impactors and methods relating to pedestrian protection mean that the CAE process can be complex and time consuming. The Oasys tools aid in this process. These tools are available for both head and leg impact analyses and have been used successfully on past and current vehicle design projects within Arup and in OEM's to accelerate the workflow. This paper gives an overview of the tools, with a focus on the latest features introduced to the recent releases of the Oasys LS-DYNA Environment – The **HIC Area Calculator** and the **Pedestrian Run Builder**.

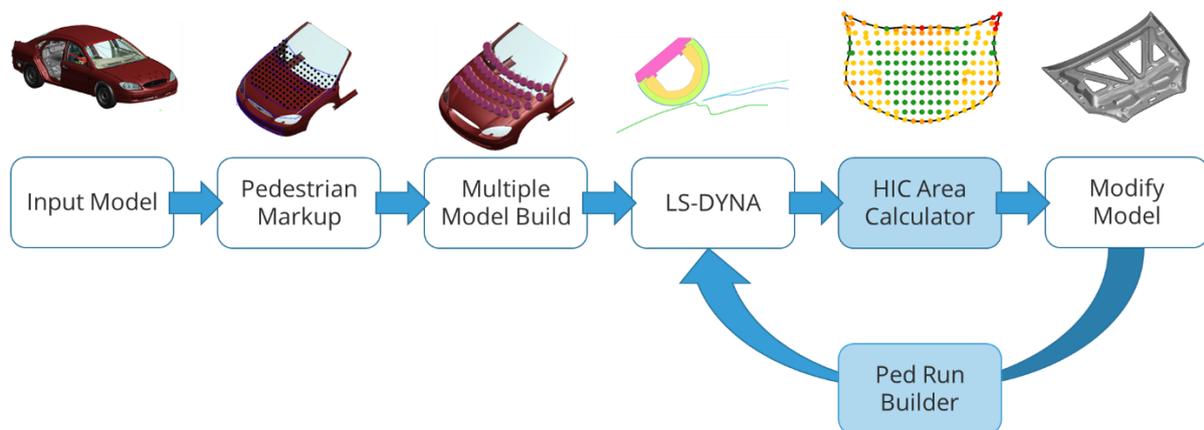


Fig.1: Pedestrian protection workflow in the Oasys LS-DYNA Environment

2 Overview

The tools within the Oasys LS-DYNA Environment can broadly be grouped into **Mark-Up**, **Model Build** and **Post-Processing**.

2.1 Mark-up

The mark-up tool within Oasys PRIMER can be used to identify test zones relating to various protocols (including Euro NCAP 2023 & CNAP 2022). The tool will calculate the various reference lines that form the bounds of the test zones. Once the test zones are determined, the tool can be used to create target points for head/leg impacts in several ways:

- Automatically creating a grid of target points over the zones based on specified spacing
- Manually create target points at specified locations
- Automatically determine "hard points" below the bonnet based on packaging space and create an appropriate target point on the outer surface of the bonnet based on impactor line of flight

- Create “robustness points” surrounding specified target points to investigate the sensitivity of impacting at particular locations

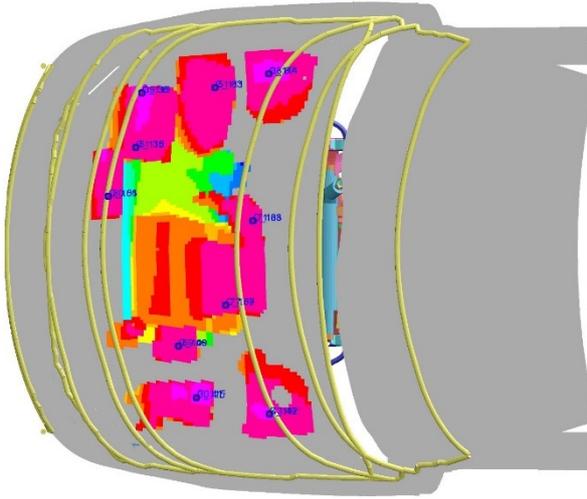


Fig.2: Zone boundary calculation and “hard point” calculation.

2.2 Model Build

Once target points have been specified, the next stage is to build multiple models automatically based on those target points. Information and files produced in the mark-up stage feed into the model build stage to make this step straightforward. Model build is done by:

- Moving the impactor to each target point in turn
- De-penetrating the impactor according to set rules
- Outputting models to run in LS-DYNA with *INCLUDE_TRANSFORM definitions to move the impactor model to the calculated starting positions



Fig.3: Multiple build of many LS-DYNA models based on target points.

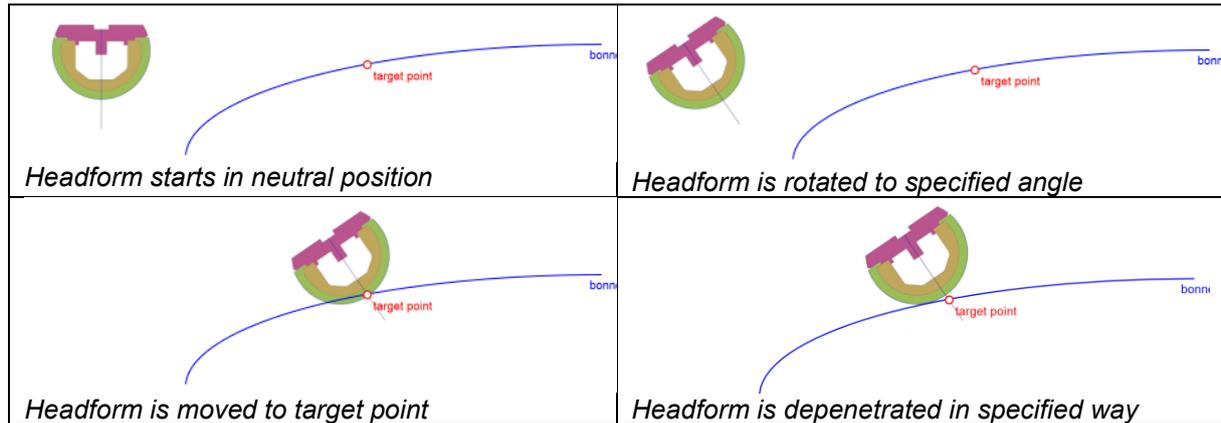


Fig.4: Positioning and de-penetrating the impactor.

There are various options available during the multiple model build process. You may wish to position the impactor such that the central point of the impactor lines up with target point along the line of flight, or you may wish to position such that the initial contact point is as close as possible to the target point.

There are also various options for how the output files are written. The default is to write a series of master decks containing `*INCLUDE_TRANSFORM` and `*DEFINE_TRANSFORMATION` definitions that reference the impactor in its neutral position. There are also options to write each impact point as a separate `*CASE` definition.

2.3 Post-Processing

The final stage is to post-process the many individual LS-DYNA analyses that are created. Reports can be created automatically using built in templates within Oasys REPORTER. This reduces the time required to manually post-process many runs. Various features are available:

- Produce individual reports for each impact
- Produce a summary report of all individual impacts
- Plot results and calculate points scored (NCAP)
- Create contour plots and “areas of HIC” from multiple analyses

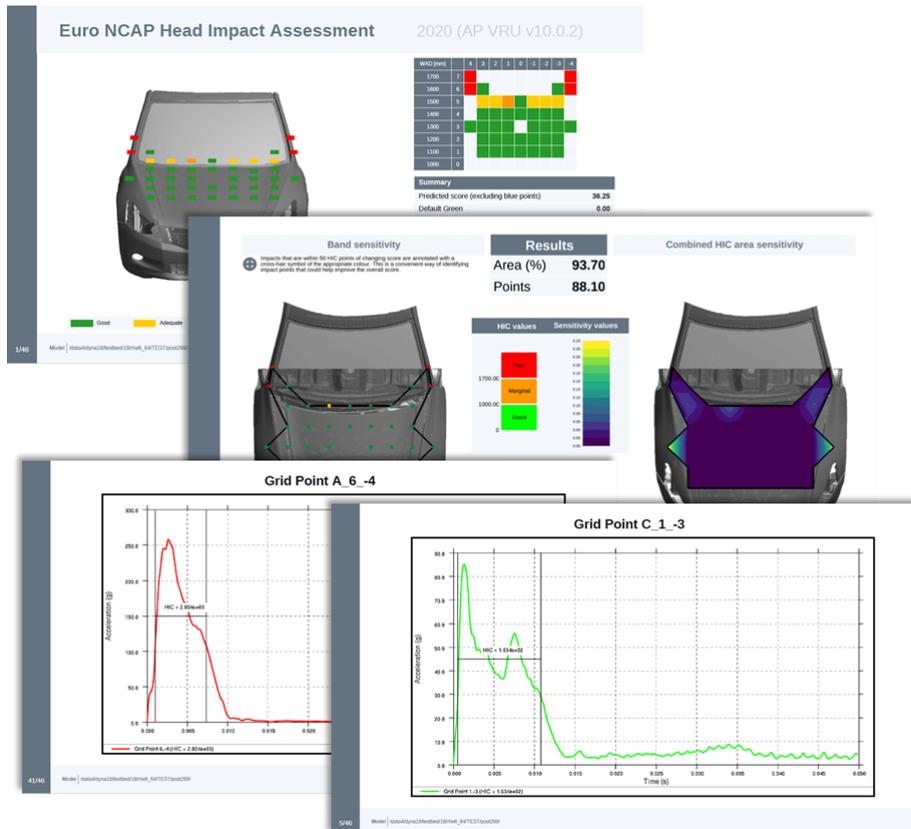


Fig.5: Oasys REPORTER pedestrian protection output

3 Latest functionality

The following new functionality has been added to recent versions, including the recently released Oasys 18.

3.1 Enhancements to the HIC Area Calculator tool

The **HIC Area Calculator** is a tool for analysing the many results that are produced during pedestrian head impact. It supports the latest GTR, Euro NCAP (including 2023) and China NCAP (including 2022) protocols, and as part of Oasys 18 has several new enhancements. This tool allows you to:

- Import HIC results and plot/contour results within your model
- Calculate “areas of HIC”, or NCAP scores
- Various tools to allow investigation of results, and identify points/areas of interest
- Comparison of results across multiple “sweeps” of analyses

The **HIC Area Calculator** is designed to give you the tools you need to make design decisions quickly within the pedestrian protection workflow.

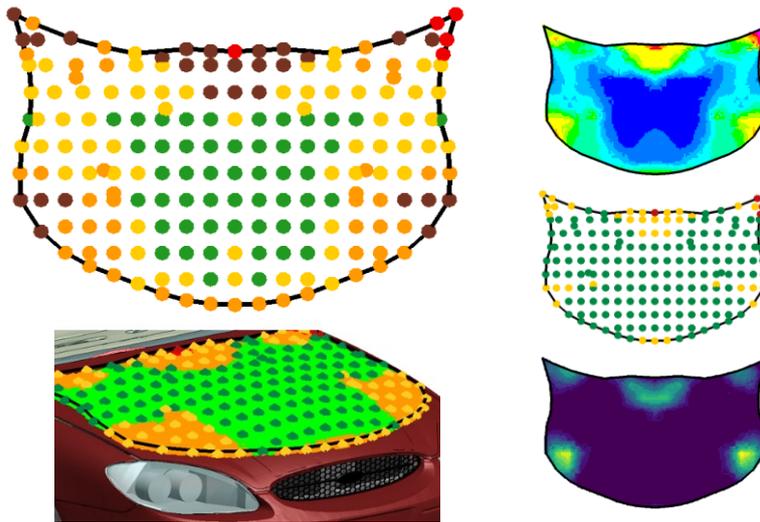


Fig.6: HIC Area Calculator results visualisations

3.1.1 Area calculation

Areas of HIC can be calculated using the tool. As well as a contour plot, a summary table provides calculated areas of HIC above/below specified limits:

	# of Points		Low HIC % by		>High
	<Low	>Low	# Points	Area	
Child	36	37	49.3 %	63.3 %	0
Adult	79	41	65.8 %	71.1 %	5
Combined	115	78	59.6 %	68.5 %	5

Determined by point names →

of Points with HIC > High HIC Limit

of Points with HIC less than and greater than Low HIC Limit.

Note: Points > Low also includes points > High

Area % as determined by point count ratio (# Points) and area calculation (Area).

Area calculations are only displayed when the specific area calculation is requested.

Fig.7: HIC Area results table

3.1.2 NCAP score calculation

As well as area calculation, you can switch to NCAP score calculation. Currently there are three regulation options:

- EuroNCAP v8
- EuroNCAP v9 (DRAFT)
- C-NCAP 2021

In this mode, data will be presented using NCAP colouring and presented in the summary table:

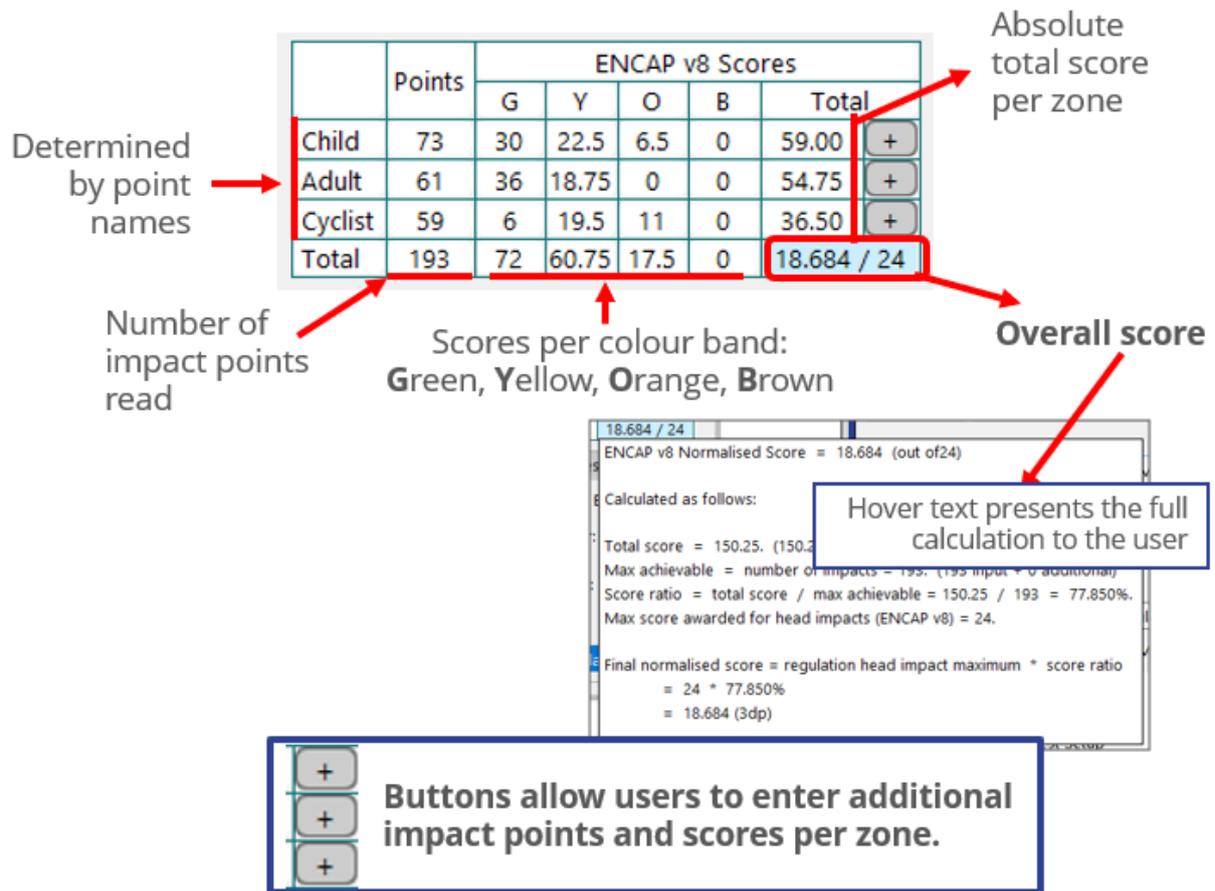


Fig.8: NCAP results table

3.1.3 Results investigation

There are various tools available to investigate the results to inform design decisions. One simple way is to edit a point value. This allows you to investigate what change you would see to areas of HIC or NCAP score if an impact point or group of impact points changes to a particular HIC value, or whose HIC values are offset or scaled by specified values. This is useful for quickly analysing “what if” type scenarios. These options are available in the “Points” tab:

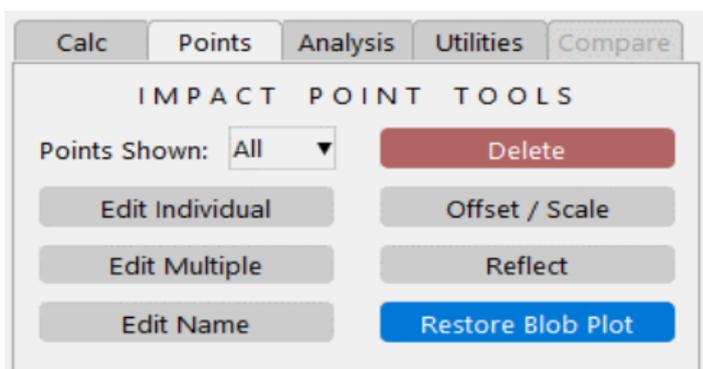


Fig.9: Points tab

The “Analysis” tab is also available to give insight into your results:

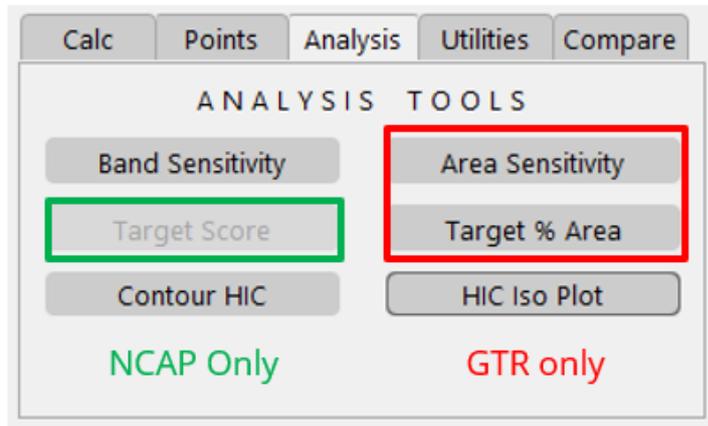


Fig.10: Analysis tab

3.1.4 Area sensitivity study

For HIC area studies. It can sometimes be difficult to identify which areas should be targeted to improve the overall low HIC % area. Some points may be close to the low HIC boundary and deemed to be 'easy wins' but have little impact to the total % area. Whereas other points may be well above the low HIC boundary but have a greater influence.

The 'Sensitivity Button' allows you to input a HIC 'delta'. PRIMER will then:

- Take one input point and add/subtract delta
- Recalculate low HIC area %
- Store change in area from baseline
- Reset input point back to original value
- Repeat with other input points

Once all input points have been analysed PRIMER will display a contour plot highlighting the areas which show the greatest sensitivity to the given delta. These areas can then be prioritised for design changes in order to improve low HIC % area.

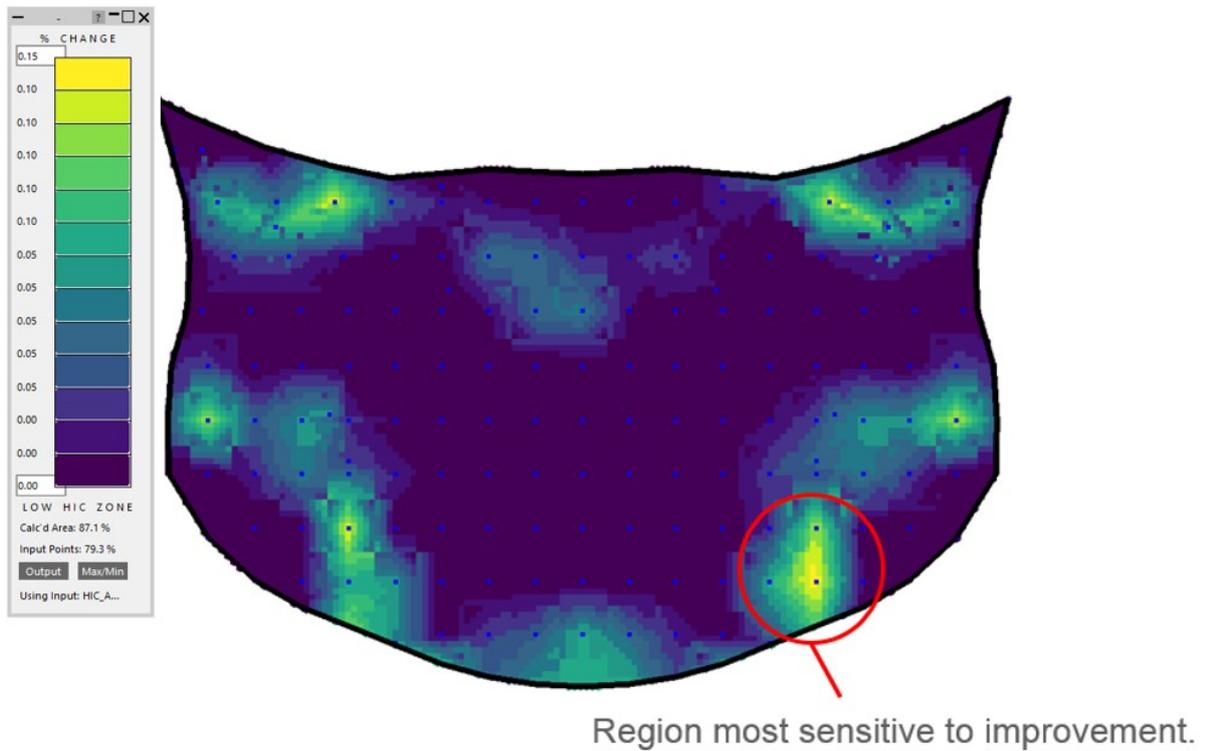


Fig.11: Area sensitively plot

3.1.5 Band sensitivity

The 'Band Sensitivity' button allows you to input a HIC value. For each impact point, PRIMER will check whether it is close to changing band (GTR or NCAP). The points will be ringed by the colour band they are close to. You then have the option to identify points that are subject to improving, getting worse, or both.

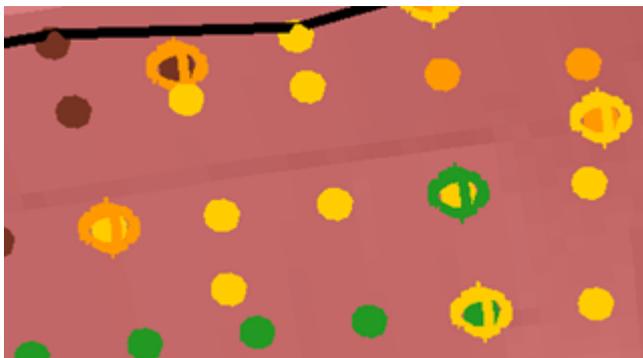


Fig.12: Band sensitivity plot

3.1.6 Target score (NCAP only)

The target score button allows you to input a target NCAP score and the tool will calculate the minimum number of points to improve in order to achieve the target value (if possible).

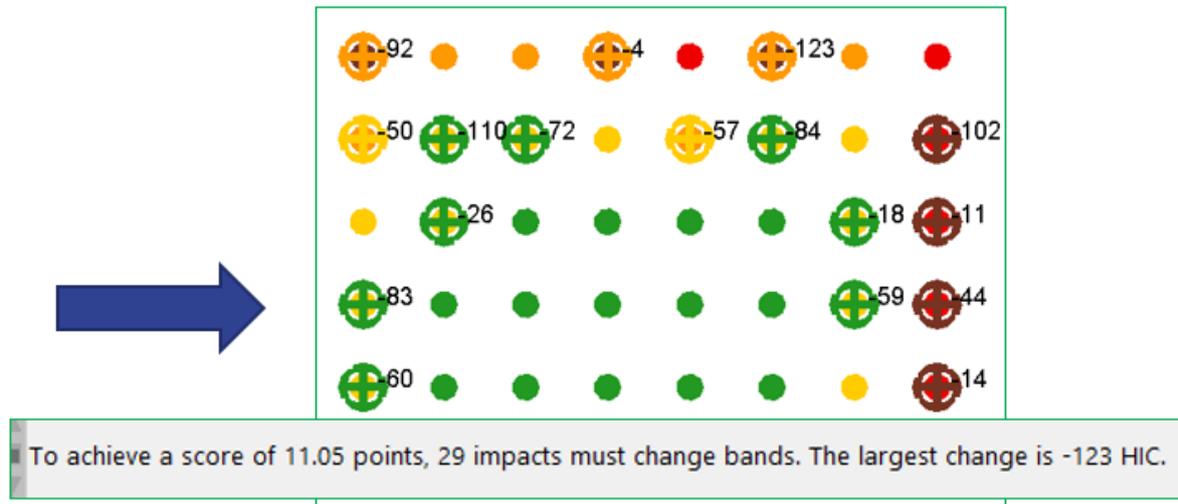


Fig.13: Target score plot

3.1.7 Comparison of results

There are also various tools available to read two sets of HIC data from different studies to compare.

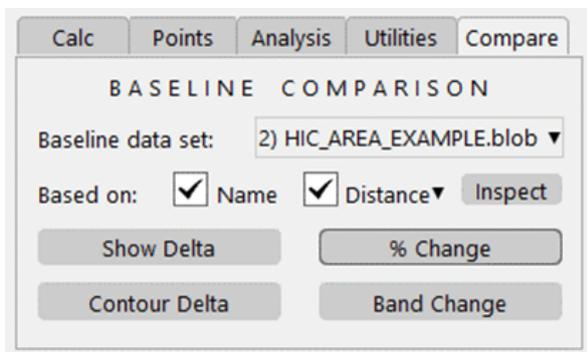


Fig.14: Result comparison panel

Different tools are available:

Show delta – Calculate the difference between two sets of data – differences of HIC are presented as text values on the screen.

Contour delta – The calculated delta values between two sets of data are contoured

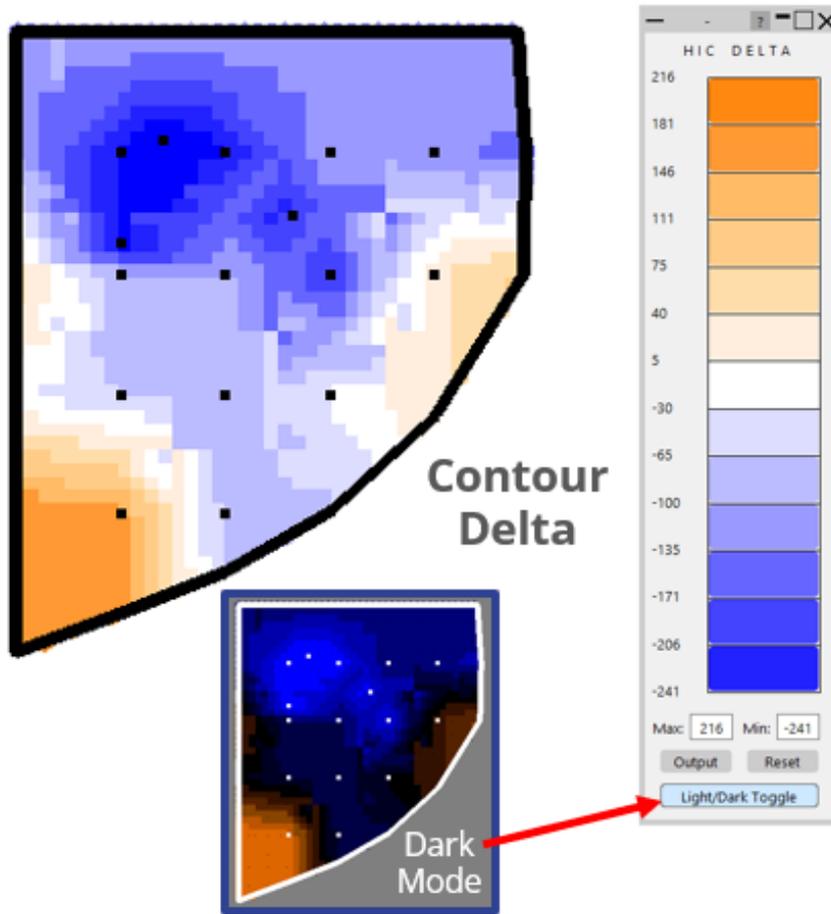


Fig.15: Delta contour plot

Band change – Highlights points that have changed banding between the two sets of results. Again, you can choose to view points getting worse, getting better, or both.

3.2 Introduction of the Pedestrian Run Builder tool

The **Pedestrian Run Builder** tool allows you to easily create a new sweep of analyses, based on an existing sweep, after a design iteration. This is an interactive way of duplicating the input models from an existing set of baseline runs, and making all the necessary changes to update those models to the design iteration you want to analyse.

3.2.1 The challenge

Duplicating file structures and files for design iterations is not always easy. This can be particularly time consuming for pedestrian analyses, where you would usually have many (>100) individual analyses for a particular design iteration. What you want to achieve is the following:

- Recreate and duplicate the file structure for the original “sweep” of analyses
- Update the models to reference a new design iteration
- Optionally, just create a subset of the full sweep (if the changes are localised in the design iteration).

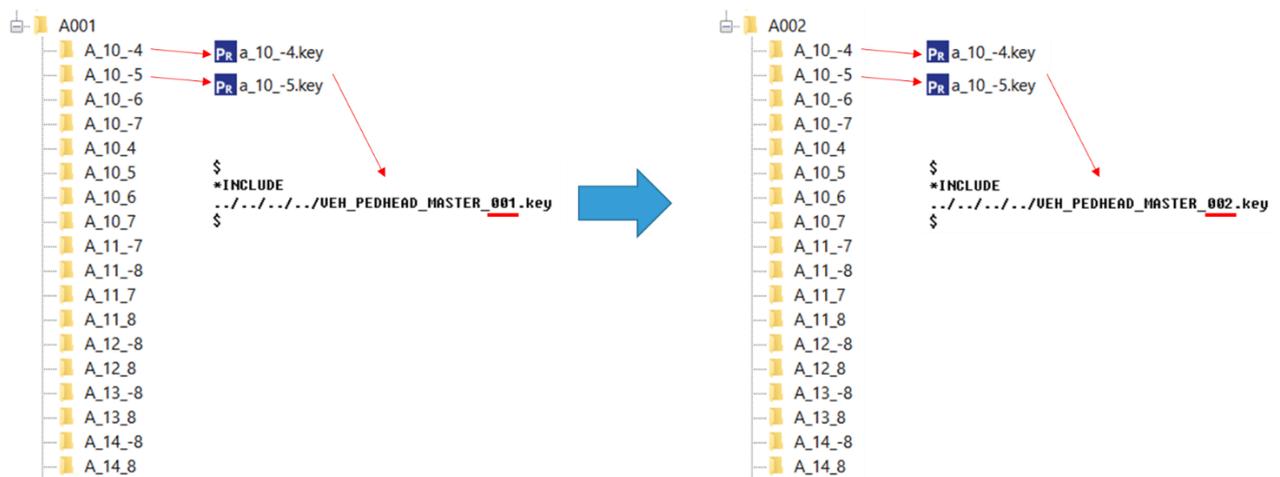


Fig.16: Process for creating a new sweep of analyses from an existing sweep

3.2.2 Pedestrian Run Builder tool

The Pedestrian Run Builder tool, introduced in Oasys 18.0, adds the required functionality to easily create multiple updated models based on a baseline set of analyses.



Fig.17: Pedestrian Run Builder tool

The Pedestrian Run Builder tool requires a list file input containing information about the sweep of baseline runs. This file is created automatically by PRIMER's Pedestrian Markup tool, or it can be created easily outside of PRIMER. It is a simple CSV file containing references to the original models and coordinates of impact points:

```
$variables,ZONE,XCOORD,YCOORD,ZCOORD
C:\VEH\PED_HEAD\A001\A_10_0\A_10_0.key,,A_10_0,2028.373901,0.000000,1082.67
C:\VEH\PED_HEAD\A001\A_10_1\A_10_1.key,,A_10_1,2028.373901,100.000000,1082.71
C:\VEH\PED_HEAD\A001\A_10_-1\A_10_-1.key,,A_10_-1,2028.373901,-100.000000,1082.71
C:\VEH\PED_HEAD\A001\A_10_2\A_10_2.key,,A_10_2,2028.373901,200.000000,1082.78
C:\VEH\PED_HEAD\A001\A_10_-2\A_10_-2.key,,A_10_-2,2028.373901,-200.000000,1082.78
C:\VEH\PED_HEAD\A001\A_10_3\A_10_3.key,,A_10_3,2028.373901,300.000000,1083.32
```

Fig.18: Pedestrian CSV list file

The Pedestrian Run Builder panel allows you to easily select the model reference you want to change/update in the design study runs, and what you want to change it to. The coordinates specified also allows PRIMER to present an interactive way of selecting which impact points you want to create and run for the new design iteration. There are tools for creating “corridors” or radii around points of interest to select regions to re-analyse:

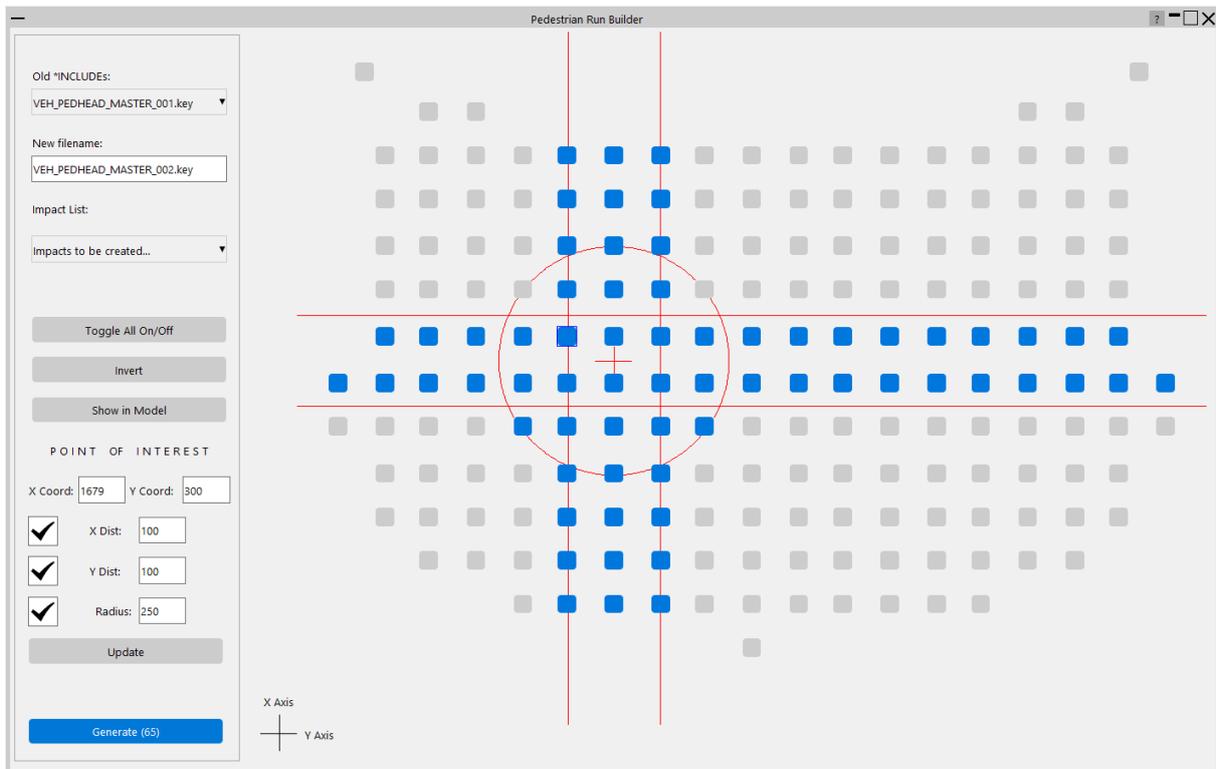


Fig. 19: Pedestrian Run Builder tool – interactively selecting points to analyse

The tool means that new studies, perhaps including hundreds of input decks, can be created quickly in a few clicks.

4 Summary

The Oasys pedestrian tools help you to produce models quickly and spend less time post-processing results. This means input to the design process can be quicker, and you have more time to investigate issues and solutions. The tools are also useful in the initial stages of development for investigating concepts relating to styling, materials, design and packaging. The recent enhancements of the **HIC Area Calculator** and the **Pedestrian Run Builder** give you further tools to accelerate the pedestrian design-analyse-decision process. Most notably:

- Direct plotting of HIC results on your model
- Automatic calculations of areas of HIC and NCAP scores
- Tools to give insight into results and inform future design changes
- Quick and interactive way to create multiple models for a new design iteration, based on an existing sweep

5 Literature

- Oasys® PRIMER 18.0 User Manual. Ove Arup & Partners Ltd: Solihull, UK, 2021