HIGH RISE COSTS

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Abstract:
In the Netherlands, the number of realized high-rise projects is limited. Until now research and development on investment costs of high-rise buildings was project or single issue based. The presented research ‘High rise costs’ is the integration and evaluation of known (European) researches into a cost model. The objective of this model is to get a detailed estimation of the building costs of a high rise office building in the initiative and early design phase, while limiting the number of required design parameters to the basics. The research started with a state-of-the-art literature review, and by interviewing experts working on high rise projects and cost modelling. This resulted in an integrated model, which is being evaluated in practice. The outcome will be a model that can be used for future design and construction initiatives. Due to national legislation and other local influences the outcome is bound to the Dutch context.

Keywords:
High-Rise, Initiative Design Phase, Integrated Cost Model

1. Introduction

A highly appreciated course at the faculty of Architecture of Delft University of Technology is the workshop “High Rise buildings”. In this course a group of students from different disciplines (Architecture, Civil Engineering, Building Technology and Management) are designing an office building with a height of 200-250 metres. They have to design this building at a location, which is not a proven high-rise spot. Subsequently, one of the major challenging tasks for the project manager is to define an acceptable estimate for a feasible building. Location, height and (Dutch) regulations combined with the required feasibility leads to a rather complicated search for right dimensions and a struggle between costs and architectural ambition. They have to make an integrated design which is based on ‘good architecture’ in order to achieve the needed high rent level. While on the other hand the same architectural highlights will cause a lot of difficulties for staying within the possible budget.

One of the instruments that can be used by the preparation of the estimate is a model developed for the initial cost estimate for office buildings, Svinsk (De Jong, 2006). This model is based on the PARAP research (Bijleveld and Gerritse, 2006). This research started with the analysis of historical data, and developed ultimately into a more designer rule based application. However the historical data as well as the designer rules are not aimed at high-rise buildings. Using these instruments does not take into account additional costs specific for high rise buildings (Langdon, 2006):

- their increased wind loadings and heavier frames
- their vertical transportation requirements, particularly elevator capacities, speed, zoning etc.
- the larger capacities of plant and distribution systems together with the increased pressures/hydraulic breaks that are required to deal with the increased vertical distances
- the effects of their scale and complexity on the movement of materials and labour
- the risks associated with their uniqueness and the fact that these risks are exacerbated by scale and the need to access a limited pool of skills and expertise
- the potential interest in including elective security and safety enhancements in response to possible risks.

Historical Dutch data can not take these effects, as summarised by Langdon, into account due to the fact that there are no buildings of that height in the Netherlands. Although there are numerous initiatives however for high rise in the range of 150 to 200 metre, that makes further research in this field valuable.

One of the means given in literature to cope with these effects is the introduction of a height charge: a factor that brings the additional costs for the specific circumstances into account. An elaborated example of such a height charge is given by Gossow (2000).

Table 1: Height charge Gossow

Height	150	200	250	Height charge
Cost (€) structural work offices per m³	140	155	170	0.0021
Cost (€) completion offices per m³	160	160	170	0.0006
Average				0.0014

The sensitivity with this height charge, especially considering the detailed effects of Langdon, is that this approach is to simple. Where some elements are influenced by the height in an extreme way, others are not changed at all.

The subject of this paper is an overview of the latest cost model by Sander van Oss (2007), in the research field of the “Cost and Quality" group of Real Estate & Housing. Previous results in this line were, amongst others Svinsk and PARAP and MSc several thesis. This paper wants to illustrate this subject by focussing on a single element of this high rise cost model, the elevator.

2. Research approach

Based upon a literature review and previous modelling and research a descriptive analysis is elaborated. The characteristics of high rise buildings are described and the essential parameters are defined. This interim result was needed for the analyses of reference projects, case studies and interviews. The interviewed experts are selected on their experience. These persons are contractors, developers and advisors with high rise experience on Dutch projects (most substantial contributors to the 20 highest buildings in the Netherlands). International contacts are selected on their publications (Davis Langdon) or by academic relations (Andreas Thieven).

The combined information is used for the draft of the model. After finishing the model the information is verified again by the interviewed parties, and tested with several real proposals in different phases, from initiatives to tendered plans.

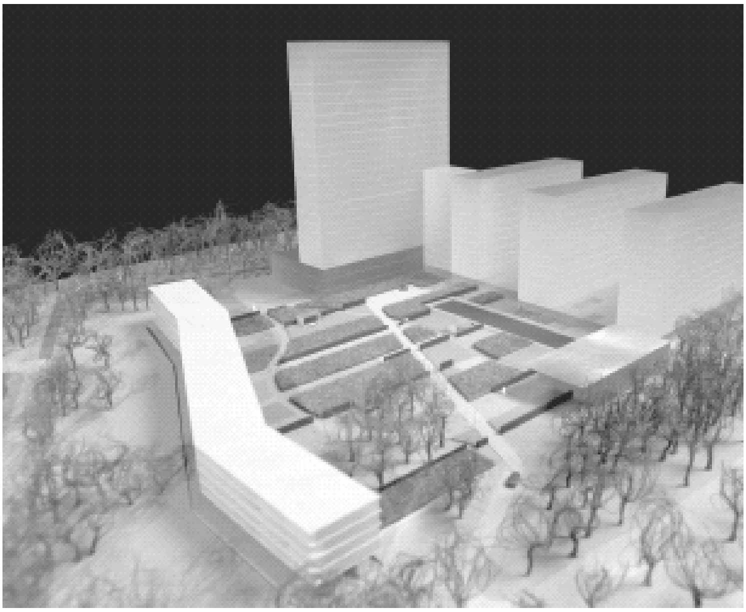

Fig. 1. Project of the Government Buildings Agency in Groningen, used for testing of the model

The research is carried out at the Faculty of Architecture of Delft University of Technology, at the Government Buildings Agency (GBA) and partly at OVG, a project development company.

3. Elevators

The model elaborates a complete building with all its building elements. The complete coverage of all building elements however is not possible in this format. The approach can be visualised with a single element. Here the elevators are described, because they are illustrative for high rise buildings. While the overall contribution to the investment costs of other elements like the roof may even decrease by the increased height, the contribution of the vertical transport to the total costs of high rise is huge in more then one view. In the next chapters the elevator costs are embedded in the total context. First the costs of the elevator itself are discussed.

3.1 The number of elevators

The number of elevators in a building is determined with several key parameters. Main key is its function. In comparison with a residential building an office building will have a complete different scope on waiting times, where traffic is peaking in a relative small time frame. The time taken from entering the building till arriving at the work place is essential for the office organisation, but also for the satisfaction of the people. Other factors are the number of people, building height, floor size and floor height. Specific for high rise the configuration of the elevators influences the costs too. Dividing elevators in groups in order to serve different building zones (in height) gives a positive contribution to the total capacity. Subsequently waiting times are shortened, the number of passengers per elevator is decreased, and elevators can be smaller and, most important of all, shaft sizes can be reduced. Too many groups in the elevator configuration will increase the number of shafts, by which the positive contribution is diminished. Above 60 floors additional arrangements can become necessary, like sky lobbies and double deck elevators. The model however is limited to 200-250 m, so these options are hardly considered.

Table 2: Number of elevator groups

Groups	Floors
1	20 – 35
2	35 – 45
3	45 – 60
4	> 60

Different calculation methods, as provided by the main elevator companies, result into slightly different divisions of groups. The model has a default group division but this can be altered for optimisation.

The model calculates on the basis of the group division, the number of floors and the number of employees the necessary transport capacity. Consequently, a lift configuration is selected listing the logical solutions.

According to Dutch regulations for an office with a height above 20 metre a special elevator for fire fighting is required, above 70 metre even two elevators are needed. These elevators, in their own separated shafts, must be able to stop on every floor. Every stop of these fire fighting elevators should land in an area with smoke separation. In practice these requirements are often met by modification of the group reaching the highest level. The elevator lobby is closed off with a fire resisting door.

The models default uses two separate fire fighting elevators, but the option to combine the fire fighting elevators with the highest group is given.

3.2 Required space

The elevators take up a considerable portion of the gross floor area (GFA). In the Dutch regulations these square metres are normally not part of the let able floor area (LA). Minimisation of this space is crucial for the financial feasibility of the building.

Table 3: use of space with different configurations (Rentier)

Lifting capacity [kg]	Number of elevators				
	4	6	8	10	12
630	8.0				
800	9.2	14.0			
1000	9.2	17.5	23.5	29.4	35.9
1250	12.4	18.9	25.3	31.7	38.6
1600	14.0	21.3	28.6	35.9	43.7
2500	18.5	28.1	37.6	47.2	56.8

For example, in an office building of 50 floors with 50 000 m^2 GFA the model calculates an elevator scheme with 3 groups with 4 elevators each with a capacity of 1000 kg, and in addition the two fire fighting elevators. This scheme requires approximately 90 m^2 per floor and in total 2260 m^2 (4.5 %), including the elevator installation.

3.3 Elevator costs

The costs of an elevator consist of:

- the basic installation,
- a surcharge for additional stops,

- a surcharge for passed stops,
- a surcharge for groups.

The example results in € 650 000 for the first group (18 floors), € 1 018 000 for the second group (34 floors), € 1 154 000 for the third group (50 floors), € 770 000 for the first fire fighting (person) elevator and € 944 000 for the second fire fighting (service) elevator. The total costs are € 4.5 million.

3.4 References

Seven experts are consulted on this subject. The results of these consultations are represented in fig. 2. The thick line represents the model. Up to 30 floors all experts agree on the level of costs. Above 100m there is less experience in the Netherlands, and consequently expectations start to divergence. The largest deviation is of the consultancy company Deerns, depending on their philosophy, in which a sky lobby is used already at 160 m. The other experts start at the level of 200 m with these kinds of adjustments, as does the model.

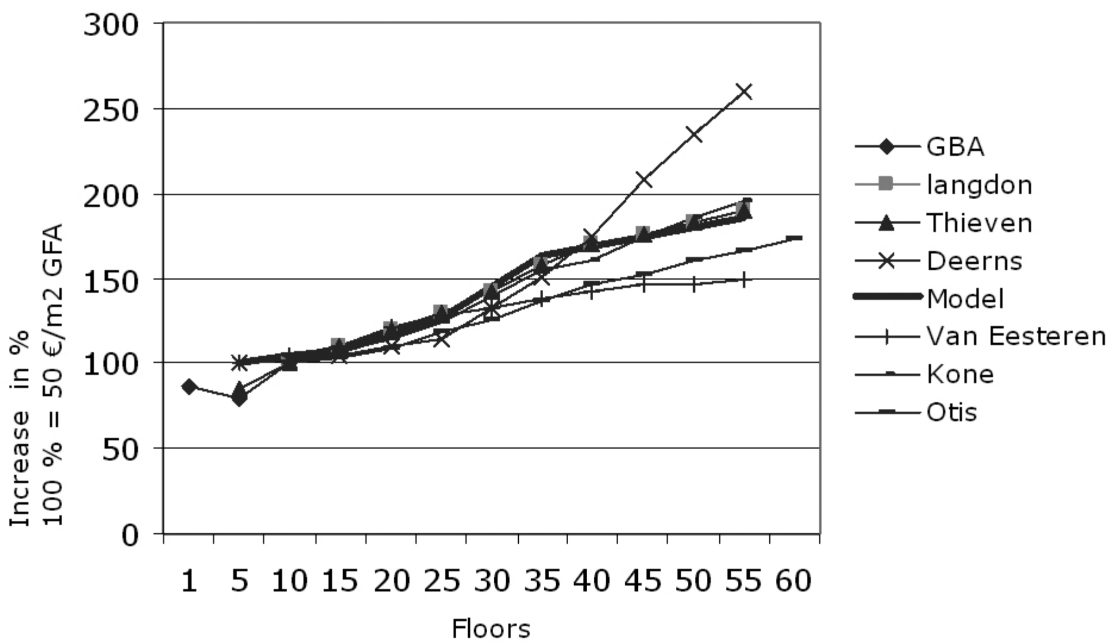

Fig. 2. Costs elevators

4. Building efficiency

The costs of the elevators may be massive. The real contribution is given by the possession of floor space. Including the required elevators for fire fighting elevators in the previous example of the building of 50 floors, the elevators could take up almost 5 % of the gross floor area, in which other vertical transport, staircases and service shafts, is not included yet.

Feasibility of high rise is a matter of controlling the efficiency of the building. Not only the building process itself but also the high rise building in use may be compared to the making of a ship model in a bottle. Every piece of material has to pass the bottleneck, making the logistics, the vertical transport, exceptionally important.

Table 4: Building efficiency (GFA/LA-ratio) (Langdon)

Number of floors	Efficiency (%)
2 to 4	88 – 91
5 to 9	84 – 88
10 to 19	77 – 85
20 to 29	75 – 83
30 to 39	74 – 79
40 +	72 – 77

The table above (Langdon) shows that where the costs are increasing with the height, the earning capacity of the building is decreasing, in which the vertical transport with the 5 % of the GFA for the elevators takes its substantial contribution.

The graph with a similar result of the model shows a similar decrease of efficiency, but here the number of floors is combined with the floor area. This is making clear that the worst results in the sense of efficiency and feasibility are appearing with tall buildings with small floor plans. Unfortunately Dutch labour legislation (daylight requirements for office workers) is forcing into this type of building.

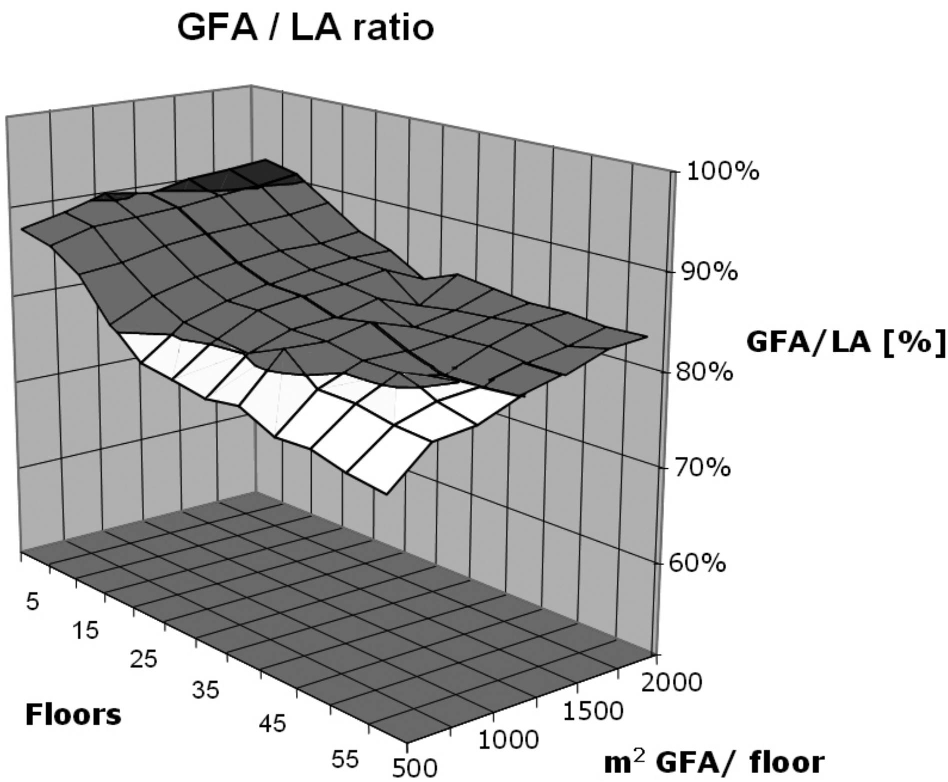

Fig. 3. Building efficiency as a result of the model

The elevators are used for explication. Another option with specific high rise characteristics would have been the facades. It is not difficult to imagine that especially the ‘tall buildings with small floor plans’ are requiring the most quantities of facades. An adequate amount of arguments to see the US as skyscrapers heaven (seen from the builders point of view), only due to the fact that floor plans of 70x70 m^2 (Sears Tower) are possible there.

One of the reasons the approximately 165 m high office building of OVG (fig. 4) is still feasible is because of smart use of let able floor area in the core. The whole approach of this building was to raise the efficiency.

Fig. 4. Maas Tower, initiative of OVG, used for testing

5. Results

Building height has a large impact on building costs. The foundation takes on average a small part and is not increasing spectacular. Structure, good for 16% of the total costs on average

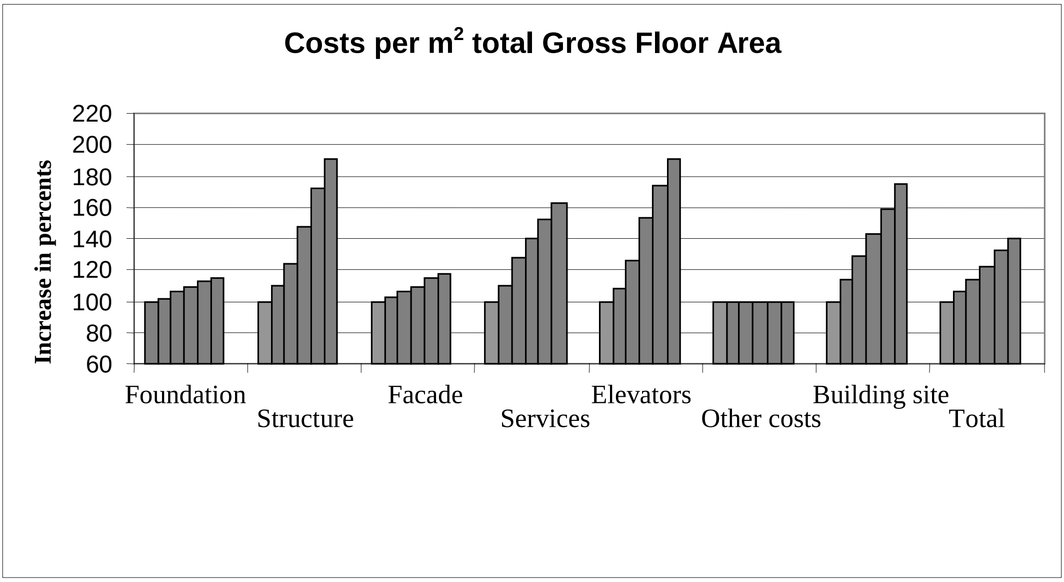

Fig. 5 Costs per cluster of 10 floors

is increasing with 10 to 15 % per 10 floors. Main reasons are increasing loads and stability influences. Facades (18%) are increasing with 3-4% per 10 floors. The costs for services (25%) are increasing with 10-15% per 10 floors, very much depending of floor size, and related to this size, the number of devices. The costs of elevators are increasing with 15-20% per 10 floors, due to advanced installations, higher speeds and increasing fire fighting requirements.

Building site costs are also investigated. They will increase by approximately 1.5 % per floor. Very complex situations, like '30 St Mary Axe' (Swiss Re) with the narrow site, hard to reach and only in a specific time frame, will tell a different, more expensive story.

6. Conclusion

The main conclusion out of this research is that building costs are increasing with approximately 8 percent per 10 floors. This increase is mainly caused by the additional costs of services and elevators and the additional costs of the structure.

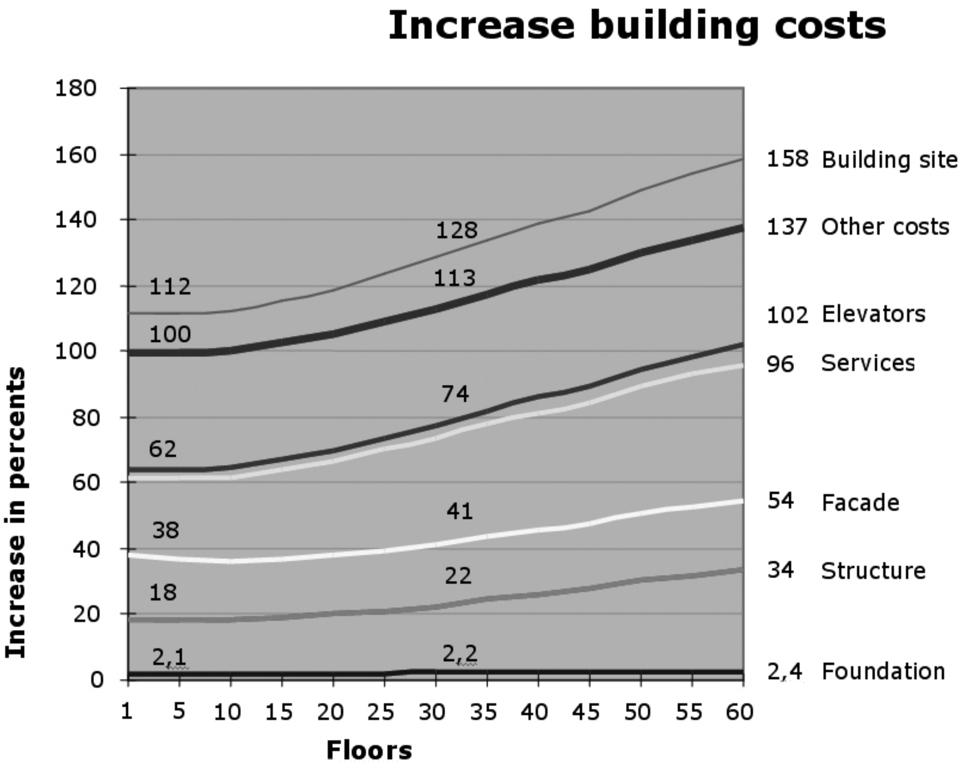

Fig. 6. Increase of building costs

The first acknowledgement should be made to Gossow. The simplicity of his height charge is confirmed. Recalculating the height charge (table 1) to a comparable figure will also give a raise between 7 and 8 percent per 10 floors, a deviation which could easily be interpret by differences in time, country and research approach.

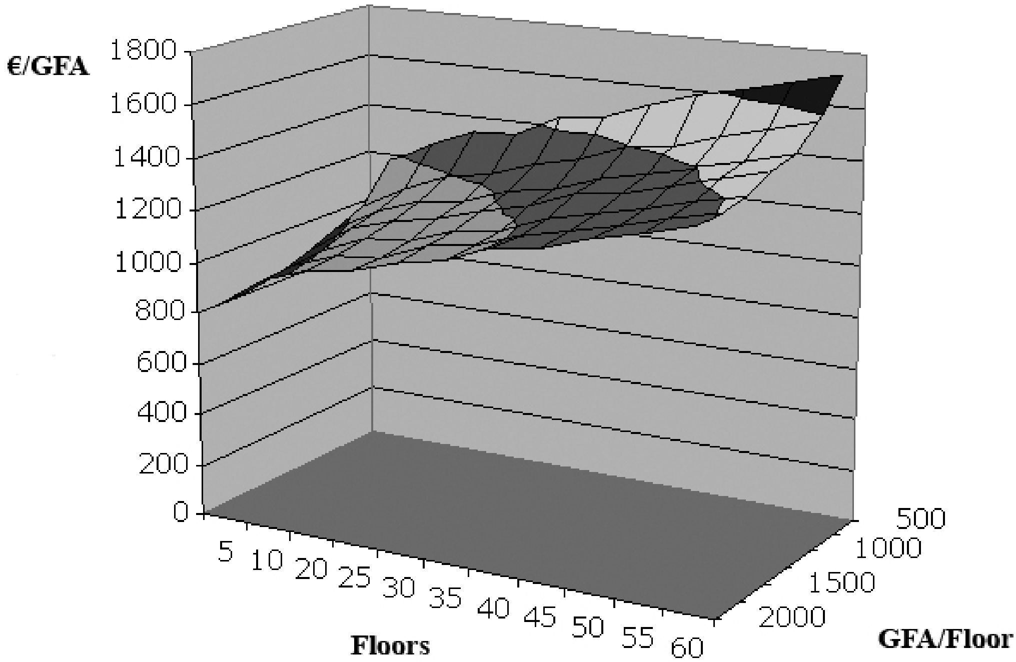

Fig. 7. building costs per m^2/GFA

Floor size is a key factor. The difference between floor sizes of 500 and 2000 m^2 could be € 300 m^2/GFA. Form and quality level do have a substantial impact on the investment cost, but rather comparable with low rise buildings.

7. Further research

In this period the model is tested in the field by setting up the estimate and comparing the results with tenders. Especially the possibility of discussion with the contractors on the deviations between model and tender gives remarkable insight at both sides. Additional research is scheduled on:

- the relation of costs of land and high rise, in general and specific for the model
- extension on different construction techniques. The model is now based on the use of concrete, where steel is an important mean as well. Furthermore detailed effects of outriggers should be taken into account.
- climate systems in combination with the facades are calculated but not evaluated by the model. A more intelligent approach could give more guidance during the initiative phase for which the model is developed.

- costs is important for the realisation of high rise, but the efficiency of the building in terms of ratio between let able, useable and gross floor area gives more insight for steering by the developer. The model would benefit from optimising techniques.

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