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Radical Refrigeration – Holistic Optimisation of Supermarket Refrigeration and its Impacts on Key Performance Indicators

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INTRODUCTION AND MOTIVATION

The food retail industry accounts for approximately 3.5% of the United Kingdom's total annual energy consumption. Associated carbon emissions of 4 Mt of contribute to 1% of the United Kingdom's annual carbon emissions [1]. Increased regulations on greenhouse gas emissions and climate change have lead to national and international climate obligations. In this context, a UK-based supermarket company has pledged to reduce its carbon emissions significantly by 30% in 2020 and by 50% in 2030.

In a typical supermarket, refrigeration accounts for approximately 50% of the total energy consumption. Therefore, optimising the refrigeration system plays a big role in mitigating climate change. Despite recent efforts to make the company's refrigeration systems more sustainable, non-incremental improvements are needed to reach the aforementioned targets.

OBJECTIVES

Assess the implications of refrigeration system efficiency improvements on a supermarket.

With focus on refrigeration, evaluate the impacts of a holistic optimisation of the supermarket on key performance indicators (KPIs).

Develop a pathway towards more sustainable refrigeration systems in a supermarket by means of three scenarios and assess the changes to the KPIs for each scenario.

Methodology

A KPI-based three layer model of a supermarket was developed. The KPIs used for the three layers of the model were:

Layer 1 - Customers: Customer satisfaction and customer shopping behaviour

Layer 2 - Sales floor: Capex, opex, product availability, shopping ergonomics and miscellaneous

Layer 3 - Engineering: Capex, opex, total environmental warming impact (TEWI) and miscellaneous

Based on a real-life base case supermarket, the impacts of efficiency improvements on every KPI of every layer were captured. Moreover, interdependencies between the KPIs of each layer were modelled. This is schematically shown in figure 1. Influences and outcomes were calculated qualitatively and quantitatively, depending on the KPI.

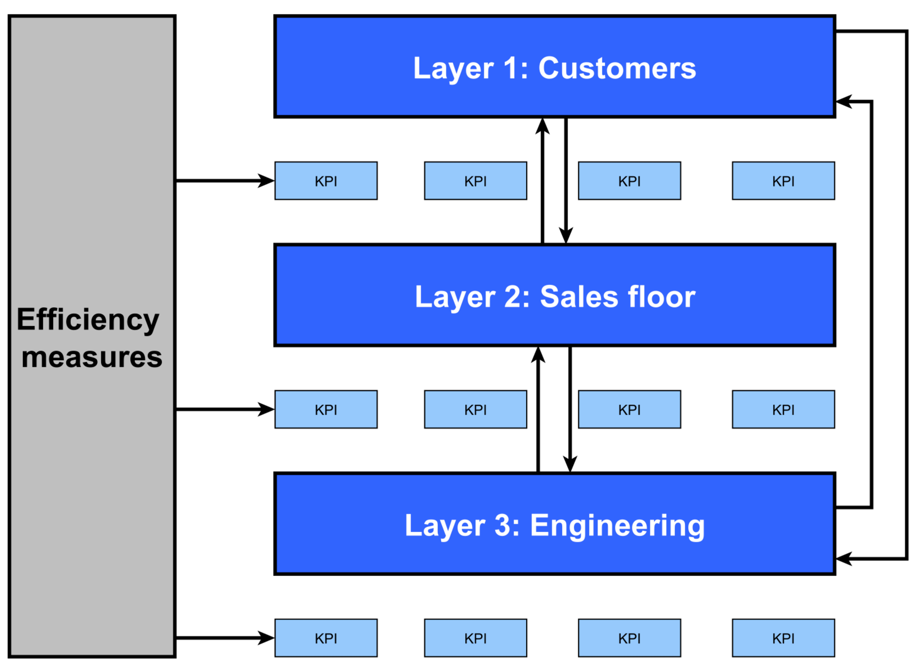

Figure 1: Conceptual schematic of the model

THE BASE CASE

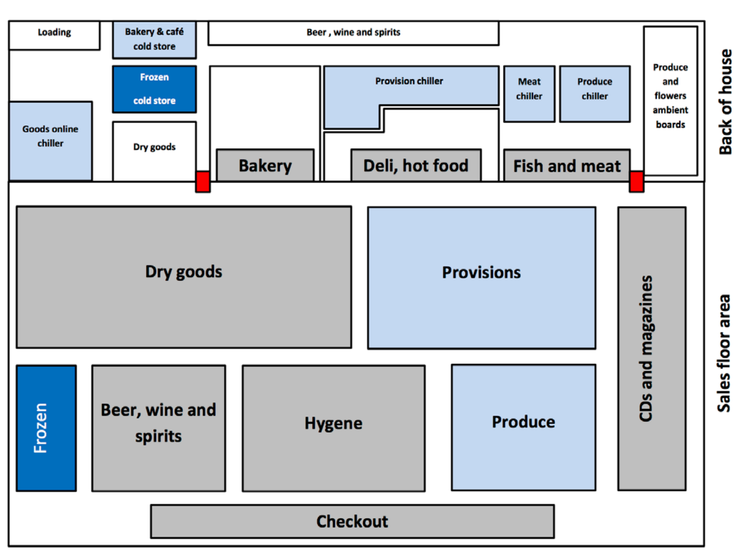

Figure 2: Schematic of the sales floor layout of the base case supermarket

The base case supermarket was defined to be a 30.000 ft2 supermarket with the refrigeration system and initial KPI values based on average numbers of the estate of a UK-based supermarket company. **Unfavourable placement** of refrigerated areas (shown in blue), **extensive piping** requirements for the refrigeration system and **long replenishment paths** for the refrigerated product sections were some of the identified shortcomings of the base case.

SCENARIOS

Various improvement measures were identified and grouped together for the scenarios. Measures affected the supermarket on a technological, operational and conceptual basis. Store layouts for the three scenarios are shown in figure 3.

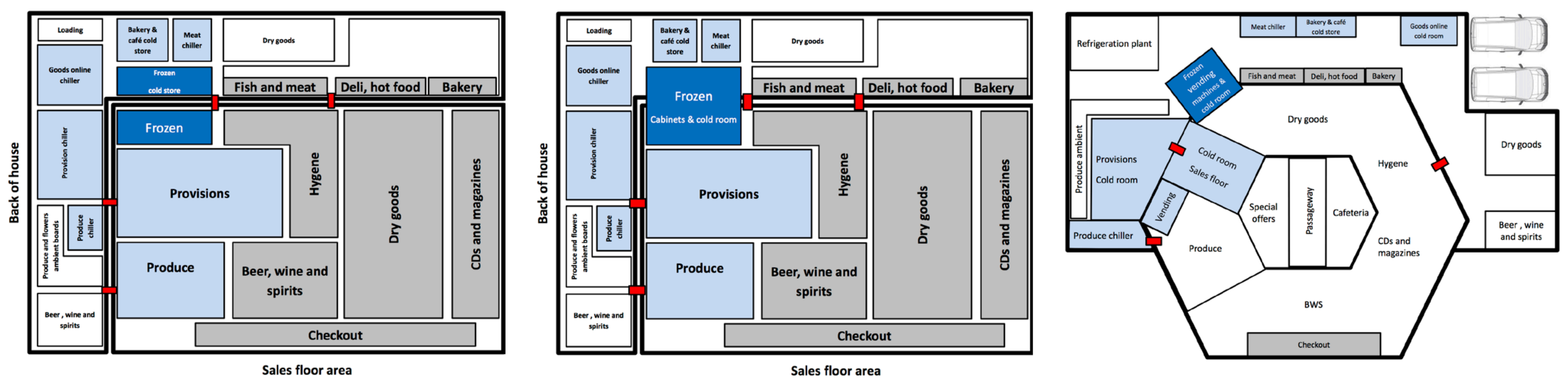

Figure 3: Schematic of the sales floor layouts of scenario 1, 2 and 3. (left to right)

Scenario 1

- Technological optimisation
- Incorporates latest technology available
- Grouping of refrigerated areas
- Optimised work paths

Scenario 2

- Evolutionary design
- Based on scenario 1
- Vending machine cabinet design for frozen products
- Additional operational optimisation

Scenario 3

- Radically new concept
- Hexagonal sales floor
- Sealed cold room on the sales floor to supersede traditional refrigerated cabinets
- Further optimised work paths

RESULTS

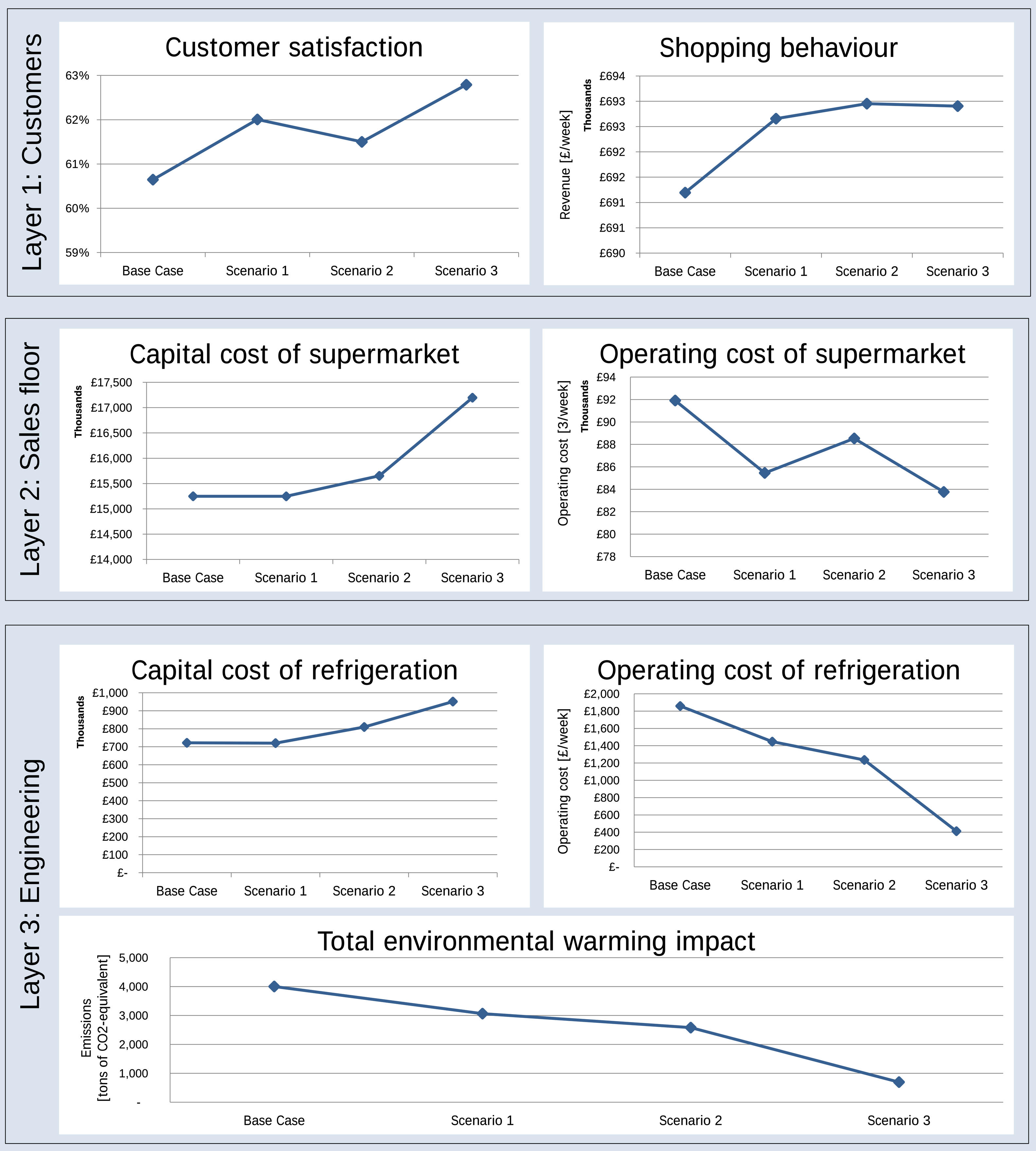

Figure 4: Results for each scenario compared to the base case for each layer

CONCLUSION

Significant emission savings could be achieved in all scenarios. **Trade-offs** had to be made regarding capital cost. These trade-offs were usually offset by substantial savings in operating cost. Optimising traditional supermarket refrigeration systems based on the current store layout was found to have limited potential. In this work, customer-related KPIs showed **limited susceptibility** even to radical changes to the status quo. Therefore, **new and comprehensive store designs** should be developed, in order to achieve non-incremental efficiency improvements and to reach the company's climate targets.

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REFERENCES

[1] Tassou et al. (2010) Energy consumption and conservation in food retailing. Applied Thermal Engineering. 31 (2-3), 147-156