Capgemini engineering

THE CHALLENGE OF CO_2 OPTIMIZATION FOR AUTOMOTIVE OEMS IN THE EU

It's time to transition from a plan-and-control to a forecast-and-adapt business model

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Executive summary

The problem

The European Union's CO_2 emissions regulation that entered into force on January 1, 2020, challenges the whole automotive industry by imposing heavy penalties of over one million EUR (MEUR) on every car manufacturer whose newly registered vehicles exceed the "average CO_2 emission per km" target. This target is set according to the average mass of their registered vehicles using a limit value curve which will steadily decrease until 2030. The economic profitability of some carmakers could clearly be at stake if they do not launch specific action plans to mitigate the penalty payments, also referred to as the premium or fine.

The challenge

For decades, carmakers have implemented and executed plan-and-control approaches for forecasting their production and sales. The complex forecast computation of CO_2 emissions coupled with the time gap between the decision (i.e., production order) and its impact (i.e., vehicle registration) make plan-and-control insufficient for accurate monitoring and management of CO_2 risks.

The solution

Thorough CO_2 penalty risk management requires additional processes and tools to optimize the production forecast in order to mitigate or even cancel the CO_2 risk, maximize the forecast commercial margin, and guarantee the overall production volume. Not solving this complex economic equation can be highly detrimental for most of the carmakers operating in the EU.

Introduction

Over the past year, CO_2 emissions have become the undisputed environmental challenge of the automobile industry. Car manufacturers have always been reluctant to take the lead on this issue, their performance being limited to the strict compliance with the laws in force. Contrary to passive safety, CO_2 emissions have not been seen as sufficiently distinctive from a customer standpoint to motivate some manufacturers to go far beyond the enforced rules.

The EU CO_2 emissions regulation that entered into force on January 1, 2020, will undoubtedly change this perspective. The regulation includes a progressive reduction of the CO_2 emissions target from 2020 to 2030 (-37.5%), which is the complete and sole responsibility of the carmakers. The assessment is based on registered not produced vehicles, with a CO_2 target computation based on the vehicle's average mass, setting up a specific target for every carmaker. The regulation includes a CO_2 penalty of 95 EUR per CO_2g in excess of the target per registered vehicle.

There will be a before and an after. The market structure will change, not only in terms of energy and powertrain. Some car manufacturers will exit the EU market because of the lack of profitability. Circumstantial cooperation and pooling between car manufacturers will occur. Operational processes from production planning to marketing expenses management will be revised and adapted to cope with these new challenges.

Beyond the necessary and already ongoing drastic review of the product ranges by the carmakers and more careful production planning, we have a deep conviction that new methods and new tools are mandatory to maintain global profitability. Indeed, the target is set on the registered vehicles and not on the produced vehicles. One may wonder what the difference is since all vehicles produced are eventually registered. While that may be correct, the time gap between production and registration can extend to between six and nine months, whereas the vehicle definition is fixed between two and three weeks before production.

Therefore, the decision processes have to be shortened, and agile feedback loops need to be introduced in order to frequently adjust and adapt the existing production and sales planning. The large number of configurations (i.e., sales constraints by country, carline, trim level, powertrain, and options, as well as production constraints) leads to unmanageable cognitive complexity. The complex adjustments (i.e., marketing and sales, manufacturing, and supply chain) require an advanced optimization tool that integrates production outputs, CO_2 emissions, and commercial margins, coupled with new operating methods that enable quick detection of any gaps between actual and forecast, and propose specific adjustments.

A standard plan-and-control approach is necessary but no longer sufficient. A more integrated adapt-and-react approach needs to be implemented.

Market context

Environmental constraints are steadily increasing on automotive sales with the entry into force in 2020 of the obligation for each manufacturer not to exceed 95g CO_2/km on average for all registered vehicles and to pay a penalty equivalent to 95 EUR per vehicle sold for each gram of CO_2 above the limit. Regulation has been further tightened with the EU target to reduce emissions in 2030 by at least 37.5% compared to 2020, which implies reducing them to less than 60g CO_2/km. A distinction is made between passenger cars (PCs) and light commercial vehicles (LCVs). For the latter, the 2020 CO_2 target is set at 147g CO_2/km with a decrease of 37.5% by 2030 to 92g CO_2/km.

This new obligation for each manufacturer to not exceed 95g CO_2/km on average for all registered vehicles is likely to have a huge impact on OEMs, representing potentially hundreds of millions of penalties hitting the bottom line. For example, a 10g CO_2 gap on two million vehicles represents a 1,900 MEUR penalty.

Achieving these targets is very complex, due not only to the shift from the New European Driving Cycle (NEDC) to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP)[1] and the target tightening, but because CO_2 emissions are now directly related to each registered vehicle's mass, including options, requiring actual sales and inventory to be monitored in real-time at the unit level. The traditional "high-level" manual optimization at year-end is no longer relevant, and the increasing commercial diversity of always more customized vehicles generates even more complexity.

CO_2 emission regulations have been in place for decades in the EU, but they have never been stringent enough to incentivize carmakers to drastically change the way they operate. Until 2020, all European carmakers have been able to meet the CO_2 targets for PCs and LCVs. They have progressively adapted their product ranges, but the main drivers for powertrain improvements have been the European regulations on exhaust pipe emissions.[2]

1 "Worldwide Harmonised Light Vehicles Test Procedure," Wikipedia

2 "European emission standards," Wikipedia

Game changers

The 2020 regulation outlined in 2009[3] has introduced two related parameters in the CO_2 equation:

1. The CO_2 emissions target is not computed on vehicle production but on registrations.

2. The CO_2 target is dependent on the average mass of the individual registered vehicle.

Thus, from a strictly operational perspective, the annual CO_2 emissions target is only known when the calendar year is over and all the vehicles have been registered. Indeed, the target is moving throughout the year, depending upon actual sales, work-in-progress (WIP), and the production forecast.

From a high-level perspective, the difference between production orders and vehicle registrations may seem minute since all the produced vehicles are eventually registered. But in the automotive industry, there is no inventory destruction as might happen in the food and fast-moving consumer goods industries. Therefore, a proper plan-and-control process could easily address this CO_2 challenge.

However, an in-depth analysis of the vehicle flow between production order definition and vehicle registration shows a distributed time gap between these two events and which features vary depending on the country, calendar month, market segment, and sales channel. It also shows that this time lag distribution usually presents a significant longtail, making irrelevant some straightforward average calculation. It usually takes around nine months to register all the vehicles produced in a certain month. (See Figure 1.)

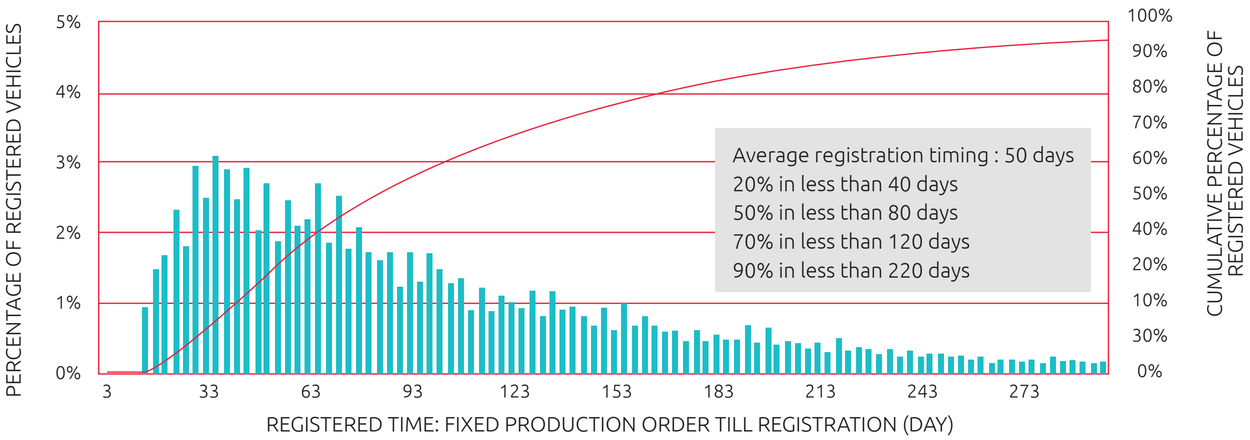

Figure 1: An example of the time gap between production order and vehicle registration
Source: Capgemini Engineering

The graph presents, in blue, the probability density function of the time gap between when the production order is fixed and the date of vehicle registration (i.e., property transfer from the manufacturer to the customer) and, in red, the cumulative distribution function. It shows that half of the vehicles are registered within 80 days after the production order and 90% within 220 days. This long distribution tail has a direct impact on CO_2 monitoring and optimization.

3 Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23rd April 2009 set emission performance standards for new passenger cars as part of the European Community's integrated approach to reduce CO2 emissions from light-duty vehicles. See also, Regulation (EU) No 333/2014 of the European parliament and of the Council of 11 March 2014, Commission Delegated Regulation
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The other game-changer is the introduction of a CO_2 penalty in the case of a CO_2 emissions target overrun and its potential impact on the commercial margin per registered vehicle.[4] Indeed, it is preferable for automakers to favor the production and vehicle sales version with the highest commercial margin for identical CO_2 emissions. In addition, a detailed sales analysis shows there is a positive correlation between the CO_2 emissions and the commercial margin of a registered vehicle, meaning that the more profitable products are the ones with relatively high CO_2 emissions. Conversely, the most CO_2-efficient products (i.e., BEV, HEV, and PHEV) show some of the lowest commercial margins. Therefore, there are no straightforward marketing and sales strategies for complying with the CO_2 regulations. A systematic and continuous arbitration needs to be done between lowering CO_2 emissions and increasing the commercial margin.

4 The commercial margin or operating margin is equal to paid price minus production cost minus transportation cost minus variable marketing expenses.

Challenges

Beyond the adjustment of the product range (i.e., body line and powertrain), automotive OEMs must change the production ordering processes. CO_2 and margin should be monitored daily and weekly. Production orders should be continuously reassessed and adjusted to limit the CO_2 penalty and maximize production and margin due to the long tail of the delivery distribution.

Moreover, the regulation may even be further tightened with a target to reduce emissions beyond the 2030 target (i.e., -37.5%) in the coming years.[5]

Cracking this regulatory issue is complex because it integrates constraints of different kinds (i.e., sales, production, parts supply, vehicle distribution, CO_2 emissions, mass per vehicle, commercial ranges, commercial objectives, financial margin, customers' choice, market share, subsidies, competitor moves, etc.). In addition, there is a time dynamic (i.e., the delay between production scheduling and vehicle sales) that takes into account the stock in the distribution pipeline.

Option #1: New challenges but same processes – plan and control

The most straightforward action plan is to extend the traditional plan-and-control approach, defined some seventy years ago, to these new CO_2 challenges.

The main assumption of this approach is to define sales and production forecasts as CO_2 compliant. The quality of the execution will ensure full compliance with the regulations. Assuming that inventory plus WIP plus forecast production equals sales, a simple computation provides the expected average weight so the CO_2 emissions target can be achieved.

In the case of a limited and insignificant[6] gap between the forecast and actual registrations, the plan-and-control approach is meaningful.

However, there is no straightforward and guaranteed correction process in the case of a significant gap (e.g., lower market sales and excess production). For example, what versions should be cut or boosted? How to adapt the sales and marketing action plans? How to reallocate the variable marketing expenses?

Any non-optimized modification of the production plan can be an over-response (e.g., the Bullwhip Effect)[7] leading to too-low CO_2 actual emissions and a lower-than-forecast commercial margin or too-high CO_2 emissions, which results in an unwanted and unexpected CO_2 penalty that lowers overall sales profitability.

5 "The European Green New Deal," Dec. 11, 2019, European Commission
https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
6 The term "insignificant" can be debated since the EU regulation states that the CO2 target calculation is done with three digits after the decimal point.
7 "Bullwhip effect," Wikipedia
https://en.wikipedia.org/wiki/Bullwhip_effect

From an operational perspective, a standard plan-and-control process is inefficient due to the moving CO_2 target linked to the actual fleet mass at year-end. It does not provide the necessary insights to adapt the production plan in order to meet the CO_2 target. (See Figure 2.)

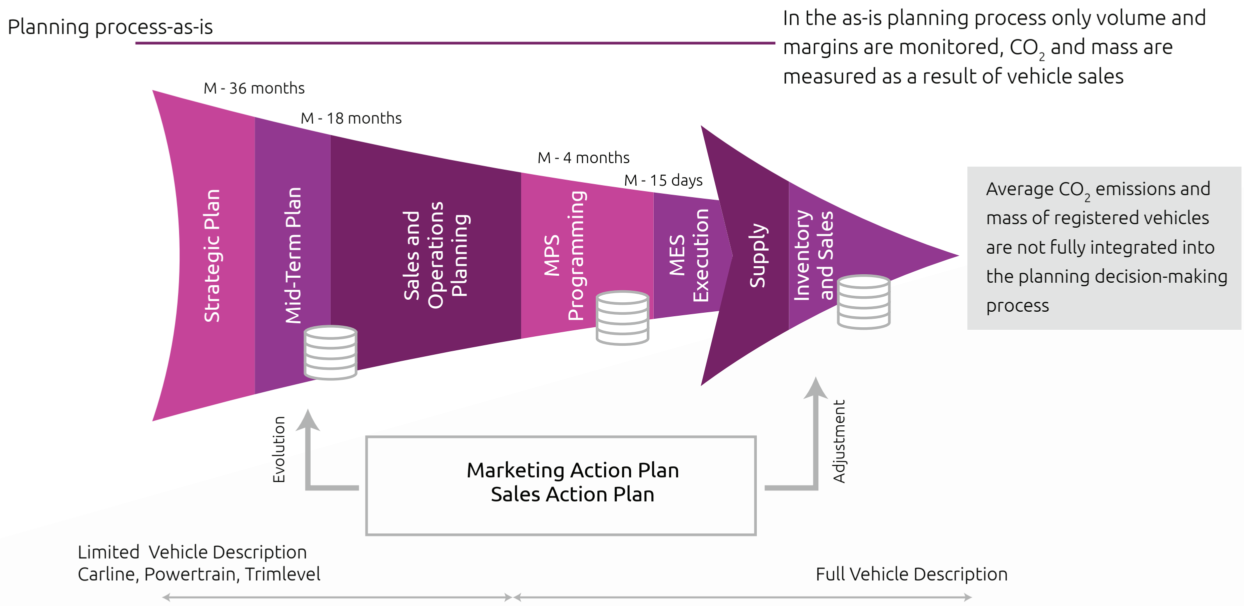


Figure 2: Planning process - as-is

Source: Capgemini Engineering

The current planning starts as early as the strategic plan, around 36 months before production, with a limited vehicle description. The marketing and sales action plans are adjusted but are mainly defined by the sales policies with a loose link with the production planning. Some KPIs are monitored, such as the commercial margin, the CO_2 emissions, and the vehicle mass. However, this traditional plan-and-control approach is inadequate when the KPI targets are moving.

Option #2: New challenges and additional new processes

The alternative is to set up some new additional but complementary processes that include closed feedback loops for order execution, order programming, and sales and operation planning (S&OP) processes. (See Figure 3.) It considers that production planning and registration planning are bi-directionally linked through time order registration patterns that exist for each quadruple: country, month, segment, sales channel.[8] Therefore, production planning can be regularly assessed and, if necessary, readjusted depending upon the actual registrations, actual inventory (i.e., national sales centers (NSCs) and dealers, and WIP). (See Figure 4.)

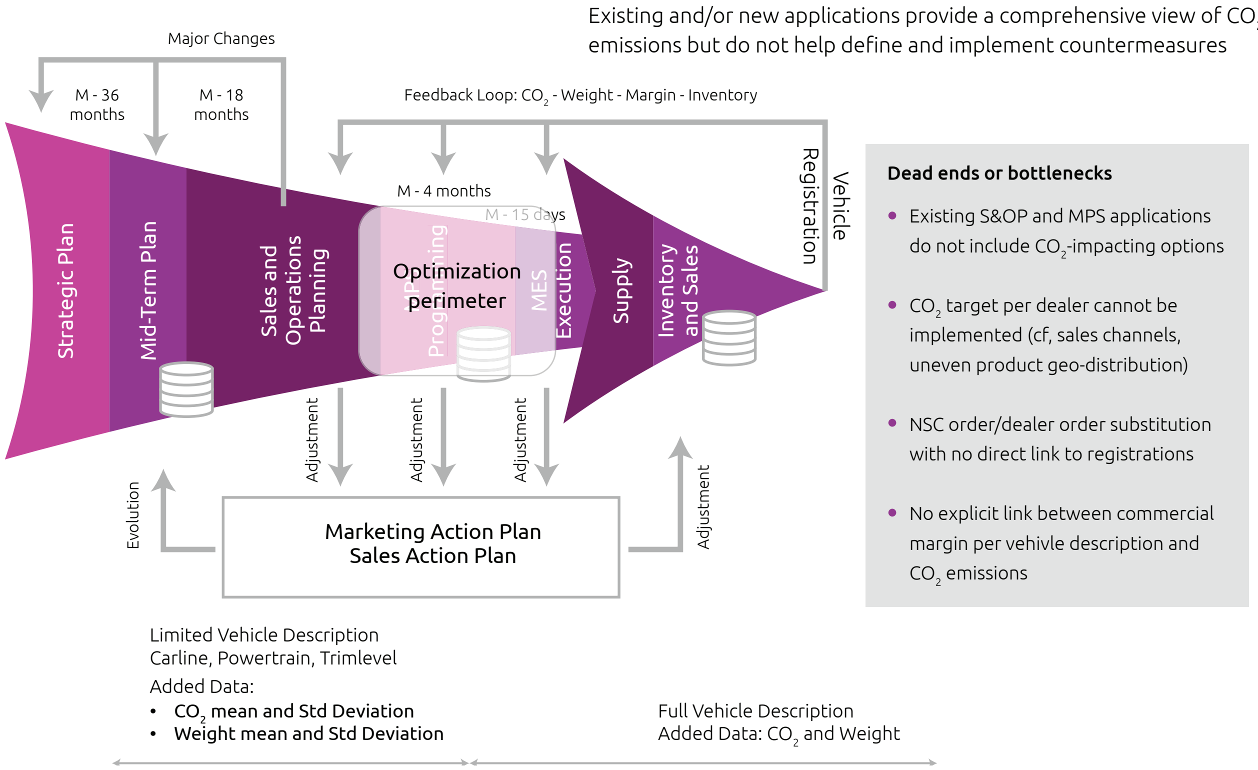


Figure 3: Upgraded planning process including feedback loops

Source: Capgemini Engineering

The existing production planning processes must be upgraded by including feedback loops. The sales and operations planning (S&OP), master production schedule (MPS), and master execution schedule (MES) must be adjusted with the vehicle registration data in order to reduce and even cancel the CO_2 penalty while maximizing the commercial margin and the production volume. The adjustment lies in the optimization of MPS and MES. In addition, marketing and sales action plans must be modified to concentrate the efforts on specific vehicle definitions compatible with the CO_2 target.

8 Time order registration patterns refer to the time between the ordering of a vehicle and its registration. It can vary from a few days (i.e., vehicle available on inventory) to months (i.e., vehicles with specific features requiring specific production).

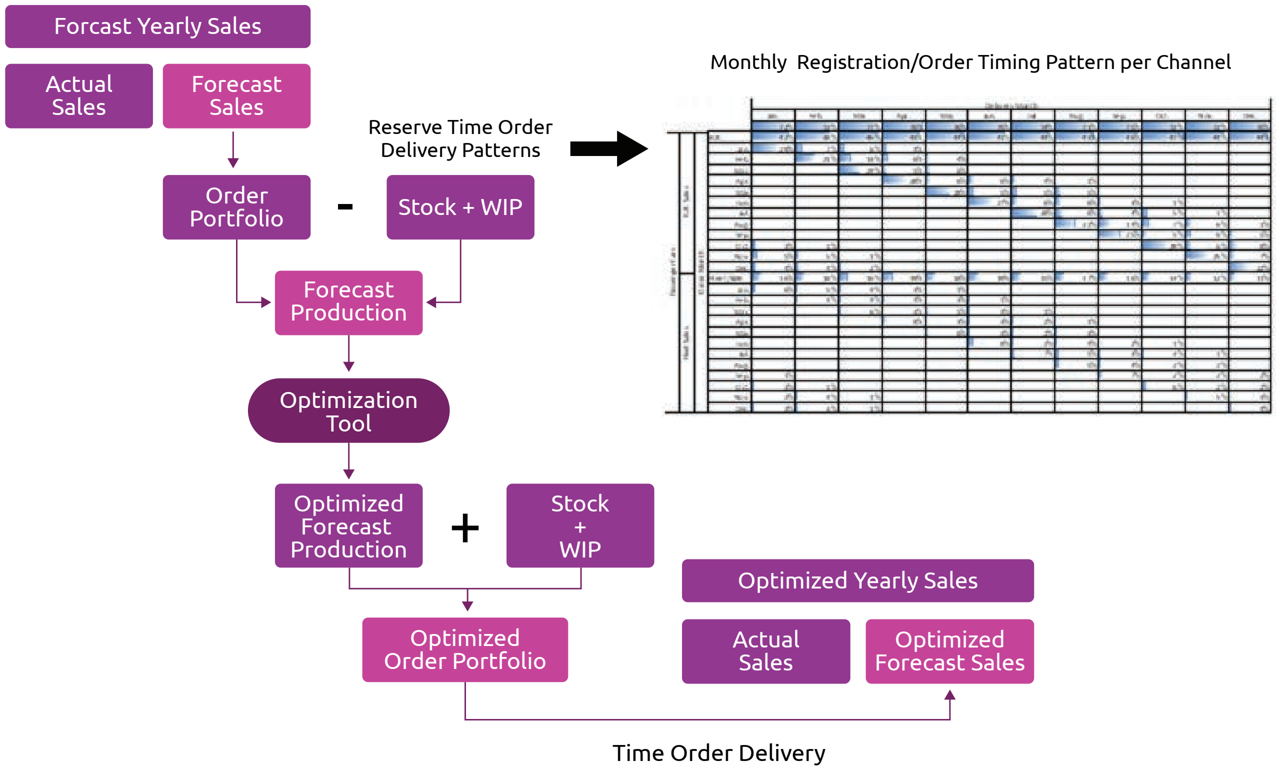


Figure 4: Macro-process optimization tool integration: from sales forecast to production
Source: Capgemini Engineering

Sales forecasts are easily derived from yearly forecasts and actual sales. Based on registration and order-timing patterns, sales forecasts can be translated into order forecasts which represent the order portfolio. Subtracting the actual stock and WIP, one can get the exact production forecast required to reach the sales forecast. After optimization, the same process is run backwards to get the optimized sales forecast. Registration and order-timing patterns are based on historical data and detailed by vehicle type and sales channel.

These closed feedback loops of order execution, order programming, and the S&OP process are compulsory to limit the bullwhip effect, which is linked most of the time to an underestimation of the WIP impact on CO_2 emissions. By putting the supply chain at the heart of this new process, the alternative approach enlarges its field of responsibility and promotes the dominance of structured data flows between design, development, manufacturing, marketing, and sales activities.

However, in order to succeed, these feedback-loop processes must be more convenient than the usual build-to-order or build-to-stock approaches, and require setting up a control tower, using a data repository, and optimizing production planning on the basis of actual sales, production forecasts per product version, and actual inventory and WIP. In addition, this optimization must include all key sales variables (i.e., CO_2, weight, volume, and margins) and integrate existing constraints, either industrial (i.e., production capacity) or commercial (i.e., market acceptance).

In addition, the proposed optimization relies on the availability of the commercial margin forecast at the version level. To our best knowledge, such a tool does not exist. One of the main reasons is to be found in the diversity of incentives and variable marketing expenses used by sales networks to develop and manage their sales. Based on anonymized data, Capgemini Engineering has developed an AI-based tool (e.g., decision trees and a random forest algorithm) to characterize the gross margin build-up logic, taking into account the vehicle technical description and the roughly decomposed variable marketing expenses. (See Figure 5.) The first forecast attempt has been made with an error below 10%.

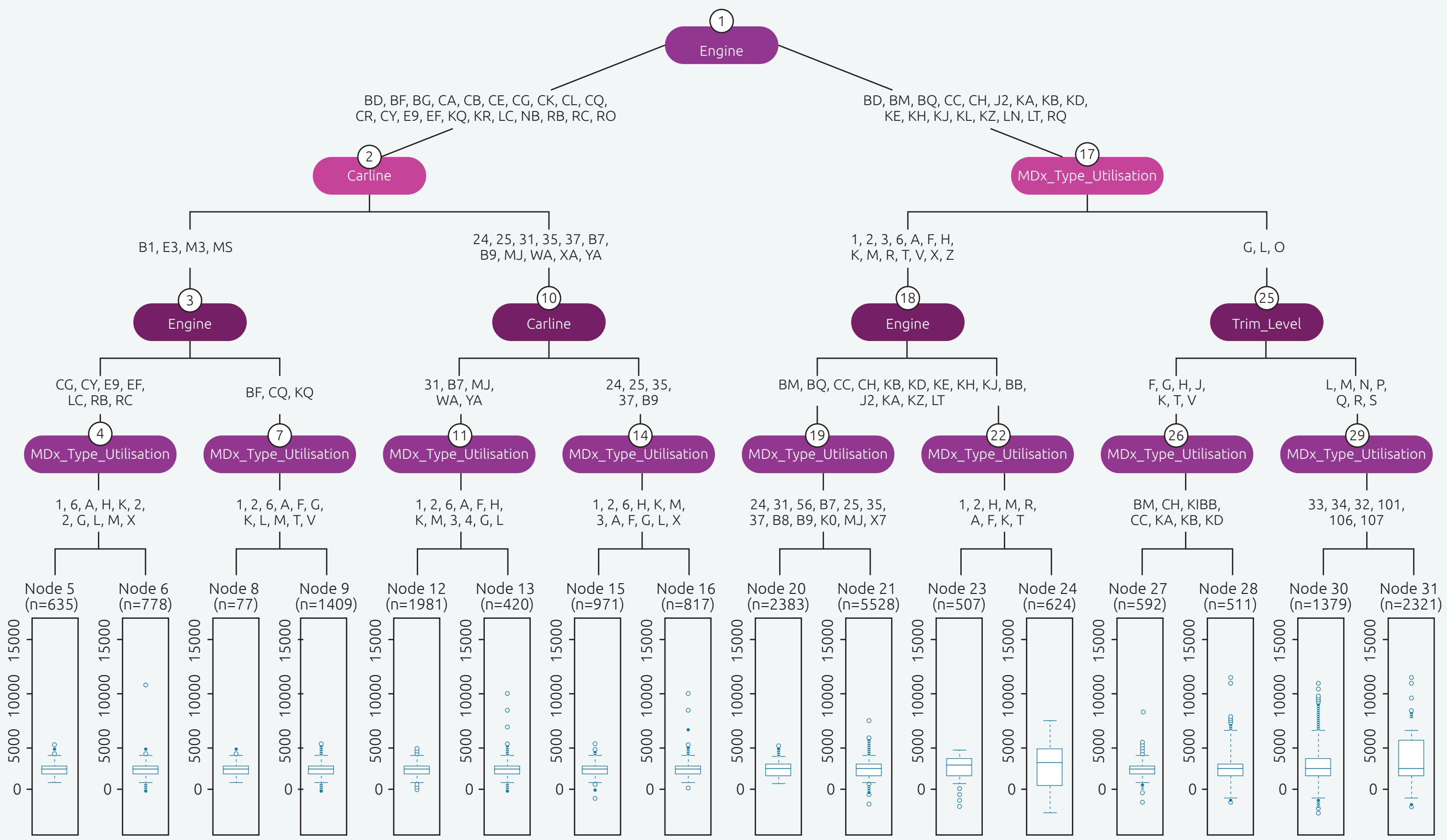


Figure 5: A decision tree characterizing the gross margin

Source: Capgemini Engineering

This classic decision tree architecture shows the hierarchy of variables, mimicking the customer decision process and the statistical data features expressed via the box plots (i.e., mean, quartiles, and distribution tails). One can notice that in certain variable combinations (i.e., the left part of the graph), the gross margin distribution is limited and, thus, can be forecast with good precision. However, for other variable combinations (i.e., the right part of the graph), the decision tree must be further developed in order to improve the forecast quality.

At the core of the Capgemini Engineering value proposition is an optimization tool that adjusts the forecast production planning from four months to eighteen months.

We have developed a demonstrator at scale on a comprehensive dummy dataset that considers the product range of a mainstream OEM with fifteen carlines, nine engines, five gearboxes, and four trim levels. Due to the shift in 2021 from the NEDC cycle to the WLTP cycle as the CO_2-emission computation reference, four levels of CO_2-related options have been added to the product range structure. In addition, a complete combination of these product dimensions has been taken into account, leading to 10,800 versions. A weight, a CO_2-emission level, a commercial margin, and monthly registration volumes have been defined for each version, with only the latter evolving over the month. (See Figure 6.)

In addition, two types of constraints have been defined:

- **Industrial constraints** affecting vehicle versions such as production-line capacity per carline, engine, powertrain and other component availability, component shortages, and product and component animation, such as launch/runout and opening/closing of series and options

- **Sales constraints** affecting specific car versions such as product acceptability, product life cycle, customer satisfaction, market trends on version and components (i.e., energy and powertrain mix), marketing and commercial policies of competitors, inventory management, sales channel seasonality and trends, fixed and variable marketing expenses, brand and product attractiveness, and brand loyalty

These constraints are already more or less taken into account in the plan-and-control approach. However, they are rarely made explicit, public, or shared between the various internal stakeholders.

Finally, a registration target and commercial margin targets have been defined and the CO_2 emissions target computed from the registration volumes and the weight of each version.

BUSINESS OBJECTIVE

Achieve Volume, Margin and CO_2 target :
2000ku, €1950 margin per unit, and 101g CO_2 fleet emissions - 10,800 car versions - 12-month production - 12g CO_2 gap

DUMMY DATASET

Each variant has a specific product mix, a mass, a CO_2 emission level, and a commercial margin

- 15 carlines - C#x - 9 engines - E#x
- 5 gearboxes - G#x - 4 trim levels - TL#x
- 4 option levels - O#x

SITUATION END OF Q1

Actual Sales	Value
CO_2	103,45
Unitary Margin (EUR)	1895
Weight (kg)	1560
Registration (unit)	500506

Inventory + WIP	Inventory + WIP
CO_2	108,45
Unitary margin (EUR)	1925
Weight (kg)	1610
Registration (unit)	164738

Current S&OP and MPS dataset:
1.43 Mu, 113,749 gCO_2
1 830EURp.u

Current Production Plan
- Prod. Vol - OK
- CO_2 Fine - Not OK
- Margin - OK

Two types of constraints:

1. **Industrial constraints affecting several car versions:**
   - Production line capacity per carline
   - Engine, powertrains, and other component availability
   - Component shortages
   - Product/components animation, launch/runout, opening/closing of series and/or options
2. **Sales constraints affecting specific car versions:**
   - Product acceptability, product life cycle, customer satisfaction
   - Market trends on version and/or components (i.e.,cycle, energy and powertrain mix)
   - Marketing and commercial policy of competitors
   - Inventory management, sales channel seasonality and trends
   - Commercial means and advertising budget
   - Brand and product attractiveness, brand loyalty

How to cancel the CO_2 penalty?

How to get an optimized production plan?

Optimized Production Plan
- Prod. Vol - OK
- CO_2 Penalty - OK
- Margin - Increased

Figure 6: Description of a multidimensional problem to solve for optimization
Source: Capgemini Engineering

A dummy vehicle product range is defined in terms of carline, engine, trim level, and options (10,000+ versions). Weight, CO_2 emissions, and commercial margin have been computed for each vehicle definition. At the end of Q1, a gap of 12 g CO_2/km is calculated based on the actual sales, inventory, WIP, and the S&OP production forecast. Two types of constraints have been identified and listed: sales constraints and industrial constraints. The problem to be solved is: how to keep the production volume at the existing level, cancel the CO_2 penalty, and increase the commercial margin.

An analytical tool has been developed and tested on this dataset. Two types of results are obtained: either a full optimization proposes a set of solutions dynamically based on all constraints considered, or the existing S&OP and MPS are taken as references for optimization. A classical multi-objective optimization has been carried out, considering that a single solution satisfying all criteria might not exist. The CO_2 penalty minimization might be overweighted compared to other variables such as margins.

We have tested the performance of our optimization tool based on a large, realistic dummy dataset designed for confidentiality reasons. A systematic study shows that the algorithm can cancel the CO_2 penalty, keep the production volume, increase the commercial margin, and in the end, find the best compromise. In this test, the net margin steadily increases with the degree of freedom given to the system. (See Figure 7.)

Current Production Plan

- Prod. Vol - OK
- CO_2 Penalty - Not OK
- Margin - OK

Optimized Production Plan

- Prod. Vol - OK
- CO_2 Penalty - OK
- Margin - Increased

Strategy : Take current overall production volume as a given. Optimize step-by-step to identify if limited volume reallocation can be lowered or canceled but also increase the commercial margin.

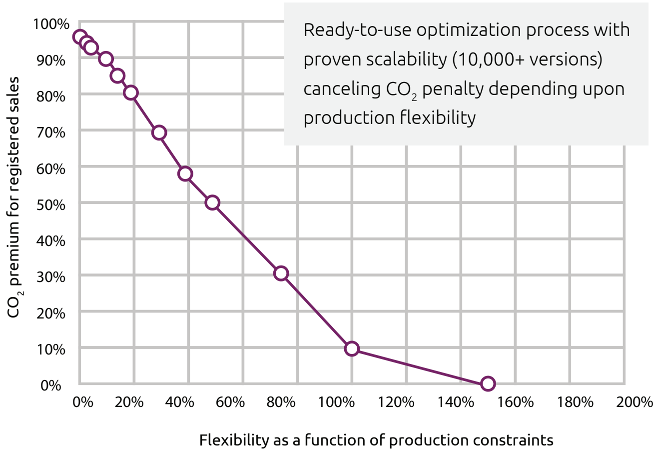
Multi-objective optimization covering CO_2 penalty, production volume and commercial margin, simulataneously

Each variant has a specific product mix, a weight, a CO_2 emission level and a commercial margin and production forecast volume over the next twelve months

Results : Under industrial and sales constraints, convergence is achieved in satisfactory computation time (e.g., a few minutes) but the CO_2 premium is slightly reduced

CO_2 penalty cancelation cannot be found in over-constrained system

Progressive release of the most limiting constraints improves the convergence and computation time and can lead to CO_2 penalty cancelation as well as commercial margin improvement



	Raw Data	+/- 1%	+/- 2%	+/- 3%	+/- 5%	+/- 10%	+/- 15%	+/- 20%	+/- 30%
CO_2 Premium	100%	96%	95%	93%	91%	86%	81%	70%	58%
Net Margin	100%	106%	107%	108%	110%	111%	120%	125%	139%
Production Volume	REF.	REF.	REF.	REF.	REF.	REF.	REF.	REF.	REF.

Figure 7: Optimization strategy: Algorithm and method implementation

Source: Capgemini Engineering

The optimization tool enables reallocation of production volume, cancels the CO_2 fine, sticks to the production targets, and increasing the net margin. The first run of optimization provides a solution but with limited improvement. The hierarchical listing of the constraints enables us to remove them one by one and see the convergence towards CO_2 penalty canceling. More than a simple black-box optimization tool, the approach works at scale and provides detailed and explicit contributions for each constraint.

The Capgemini Engineering response

Regarding the unique selling proposition, we provide an automatic and explicit balance between CO_2 emissions, production volume, and the commercial margin. Since CO_2 emissions and the commercial margin are positively correlated, an automatic and global optimum guarantees overall financial performance. (See Figure 8.)

In terms of benefits, we can outline the change management program. Indeed, the regulation requires the implementation of new and upgraded tools, and the supply chain is becoming the epicenter of automotive activity. Consequently, new processes and ways of working must be defined and implemented throughout the company at the corporate and NSC level.

There are four features:

1. CO_2 gap management

- Any actual-versus-forecast gap is identified in almost real-time, not only for the year-to-date but also at year-end, thanks to the direct connection between the sales and production forecasts using order and registration timing patterns.

- PC and LCV are managed separately but with identical tools and methods, meaning the operational solution can deal with any type of sales subtotal.

2. Ability to close the CO_2 gap and reduce or cancel the CO_2 penalty

- In the case of a gap, the impact/contribution of each constraint is assessed and ordered in almost real-time. Thus, any constraint can be explicitly lifted, and its impact on the sales forecast is directly accessible through the order/registration timing patterns. “What if” scenarios can be built and assessed before deciding to implement the production, marketing, and sales changes.

3. Role of dealers

- There are no specific CO_2 targets for dealers to set up. Their supply pipe is naturally constrained and channeled through the existing inventory and WIP pipeline and the existing production forecast. Thanks to the order/registration timing patterns, dealers can only sell what is available in inventory and what will be available soon via the production forecast.

- The treatment of demonstration cars is also under control since they are inventory-related. Their impact is already considered in the production optimization.

4. Sales channel management

- Since the order/registration timing patterns are sales-channel dependent, the diverse contribution of each sales channel is explicitly taken into account. Each sales channel will contribute to achieving the target based on their respective order/registration timing patterns.

- Production and registration are explicitly linked, so the CO_2 impact of vehicle launch/run out or the introduction of new series or options can be assessed.

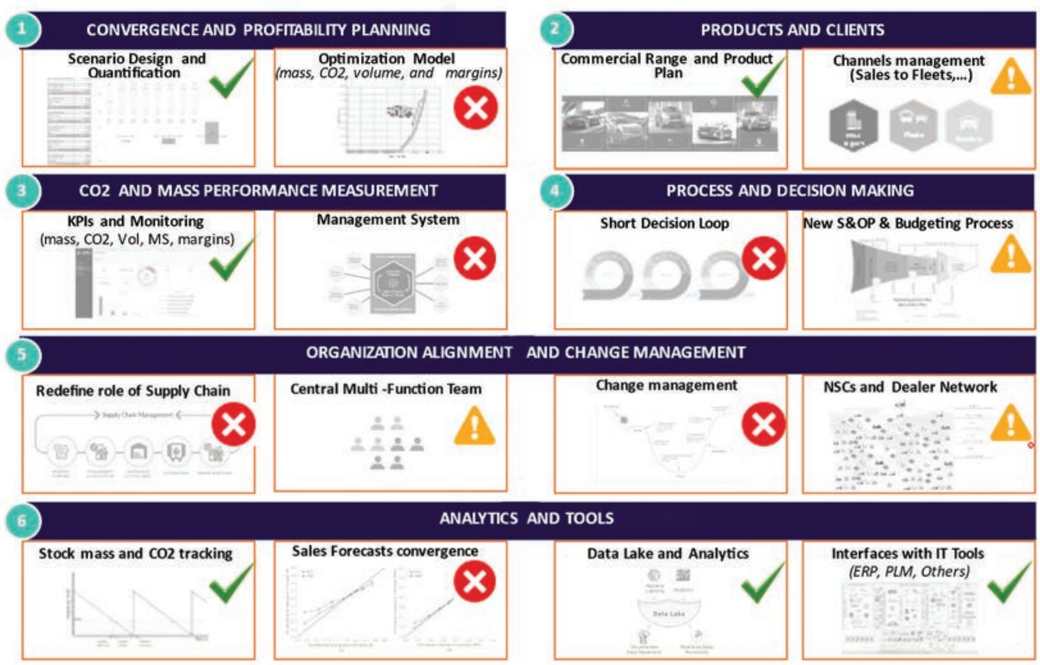


Figure 8: An example of a scorecard for an unspecified carmaker
Source: Capgemini Engineering

Six key pillars are necessary to control CO_2 fleet-emission compliance while preserving volume and margins: convergence and profitability planning, products and clients, CO_2 and mass performance measurement, process and decision making, organization alignment and change management, and analytics and tools.

Conclusion and perspective

The automotive industry is at a critical crossroads. For decades, through non-binding voluntary agreements and unrealistic emission testing cycles, car manufacturers have been able to divert responsibility for managing CO_2 emissions. One of the reasons is the direct and positive correlation between CO_2 emissions and commercial margin. In short, "why should we sell low CO_2 emission cars if we do not make money on them?"

The EU CO_2 emissions regulation, which was enacted in 2009, reinforced by the shift from NEDC to WLTP, and strengthened in 2018 with a minimum decrease of 37.5% of the CO_2 emissions target by 2030, will dramatically change the landscape and reshuffle the competition.

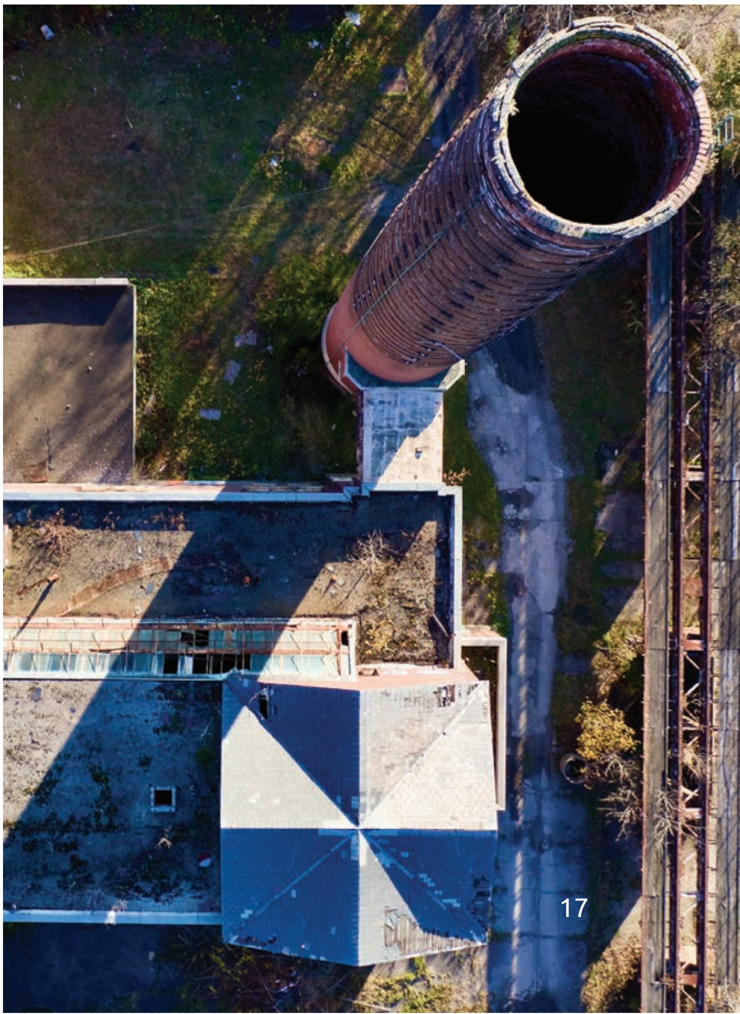
By linking the CO_2 emissions target to the registered vehicle weight and imposing a significant CO_2 penalty per car in case of CO_2 emission excess, the new 2020 CO_2 regulation will not only force car manufacturers to dramatically downsize their product range but also modify their planning processes significantly in order to be more reactive and adaptive.

A quasi-permanent adjustment between actual and forecast data is becoming compulsory, displacing the traditional "metal-push" approach, which means "what is produced will be sold regardless of consequences," especially demo cars and unprofitable leases. The CO_2 emissions target to be achieved is computed based on the registered vehicle weight. However, the time gap between the production order and vehicle registration can be up to nine or ten months, depending on the country and sales channel. As a consequence of this gap, car manufacturers must be reactive and adjust their very regular production planning process to maximize production output, minimize CO_2 emissions, and maximize the commercial margin.

To achieve this, Capgemini Engineering is proposing a complementary approach to the existing planning and tracking processes by implementing a hierarchical optimization tool at the heart of the production planning process and proposing production adjustments to precisely reach the CO_2 emissions target.

By taking into account historical ordering and registration timing patterns, the production forecast and the sales forecast are synchronized and consistent, making the CO_2 year-end landing more predictable. In addition, coupling industrial and sales constraints enables automakers to identify both the deadlocks and opportunities for improvement.

Some car manufacturers have not yet recognized the need to implement such an approach, convinced that the plan-and-control process they have used for decades will be sufficient. A sense of urgency will arise when the CO_2 emissions target is lowered year by year, and production and sales planning will not converge naturally. That's when complex, multidimensional arbitration will need to take place. But by then, it could be too late to avoid hundreds of millions of euros in CO_2 penalties.



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Pascal's expertise spans all aspects of the customer journey and activities, from foresight, strategy, and innovation to sales, marketing, and supply chain. His knowledge of operations and management complements his deep experience in the automotive sector, and more recently, urban and individual mobility.

Pascal spent 22 years with the PSA Group, rising from research engineer (1996-2000) to managing recycling and end-of-life vehicle policy in PSA's Strategy Division (2000-2003), financial controller (2003-2008), director of strategic marketing and foresight for the PSA Group (2008-2015), and project director for the PSA Group's Supply Chain Department (2016-2018).

In 2018, he joined Altran, which Capgemini acquired in April 2020. In June 2020, he was named Senior Director, Automotive Business Transformation, Capgemini Engineering.

Pascal received an engineering degree from the Polytech Paris-Sud, a doctorate from the National Institute of Applied Sciences (INSA) in Lyon, France, and a post-doctorate from the University of Cambridge, England.

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