The Beyond Planning Framework

Planning and control of large-scale projects in the age of AI

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Contents

INSIGHTS

//01

The Beyond Planning Framework provides the confidence, most companies lack in planning and control of large-scale projects.

//02

The framework combines domain expertise and artificial intelligence in dealing with complexity, constant change, and human bias.

//03

Companies with a rigorous focus on a detailed bottom-up planning and continuous feedback during execution will benefit from reduced project duration and investment costs.

01 | What is Wrong with the Management of Large-Scale Projects?

Status Quo: Bringing the project reality to the surface
The failure of complex, large-scale projects is an omnipresent topic in the media. The phenomenon appears across the world, in sectors ranging from infrastructure to production and transportation. The economic and social damage is remarkable, considering that such projects typically surpass several hundred million euros in investments, take many years to develop, and involve multiple stakeholders.

Unfortunately, the snippet covered by the media is indeed a representative one. Science confirms that complex, large-scale projects are most likely doomed to go astray. According to a recent study published by Oxford Saïd Business School, nine out of ten megaprojects exceeded budget in the last 70 years.[1] In other words, only one project is still in budget at the finish line. A cross-industry analysis for the German market confirms these findings. In addition, cost overruns vary between sectors; the vast majority of large-scale projects do not meet the intended requirements as shown in figure 1.

So why do large-scale projects tend to fail while small projects are more likely to be successful? Which of the existing underlying principles have to be adapted to succeed in project management of large-scale projects?

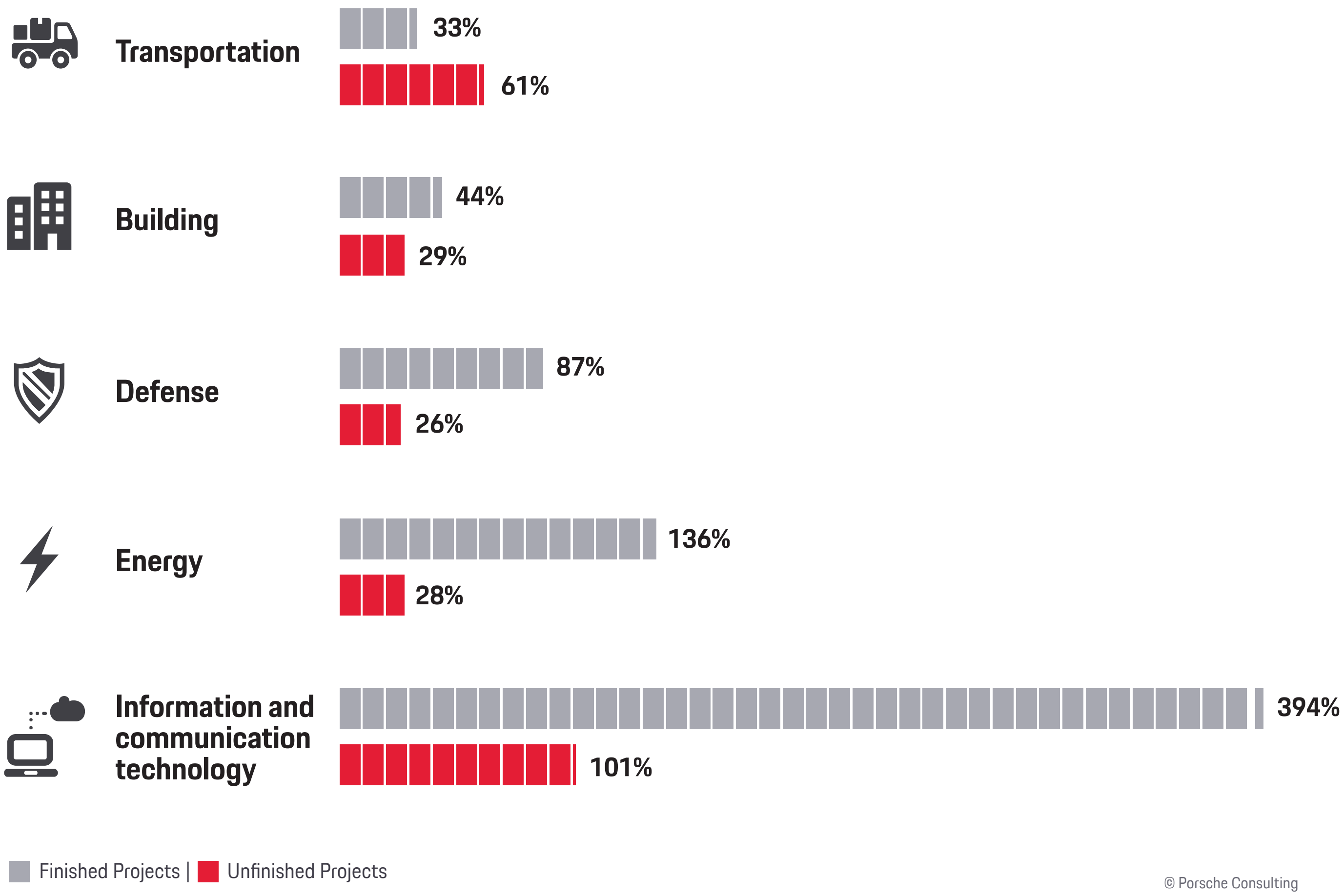

Fig 1. Budget-overruns of large scale projects depending on industry.[2]

Characteristics of large-scale projects

A PROJECT HAS TO BE WELL MANAGED TO BE CARRIED OUT SUCCESSFULLY. PROJECT MANAGEMENT IS CHARACTERIZED BY A MULTITUDE OF INFLUENTIAL FACTORS, WITH INTERDEPENDENCIES AMONG THEM. UNDERSTANDING AND CONSIDERING THESE FACTORS CAN RADICALLY REDUCE TODAY'S PROJECT FAILURE RATE.

When these three drivers occur together, failures in project management are unavoidable, and they are pervasive due to the very nature of large-scale projects.

//Complex project environments

Large-scale projects are characterized by factors ranging from the number of participating organizational units to the required extent of intercultural cooperation and the technological complexity (e.g., functionality, number of interfaces, and modules). They involve internal and external stakeholders with a different nature of interest (e.g., their behaviors, attitudes, and involvements). The tendency toward customization torpedoes the degree of complexity. With the size and the uniqueness of the project rising sky-high, defining a project holistically becomes a tedious task. Shortcutting creates a lot of uncertainty down the road.

//Constant changes

Late specification changes can lead to far-reaching changes in schedule and cost plans. The results are numerous short-cycle adjustments during the project, such as those caused by variations within the project-execution team, thereby subjecting project plans to constant attack. On top of it all, project management has to consider changing legal or environmental conditions. This is especially true for large-scale projects that face technological developments and innovations within the project duration. Realistic time and resource planning in such an environment becomes almost impossible.

//Human biases

Ninety-five percent of information processes in the brain are not rational but instinctive, with cognitive biases having their effect.[3] Working with incomplete and incorrect project plans increases the risk of irrational decisions. Too often decisions are driven by an unhealthy cocktail of underestimated costs, overestimated revenues, and flawed estimations of environmental impact and the effects of economic development. In addition, people have to keep an open mind. Otherwise projects split across countries with a high demand for interdisciplinary technical expertise can abruptly come to a halt.

Fig 2. Drivers for failure rate of large-scale projects.

Smart project management is key to countering them. A structural planning approach to multimillion euro projects is not "nice to have", it is rather an obvious cornerstone. It has to handle the existing complexity and be extendable. To do so, the internal logic has to entail degrees of freedom, for example, to connect further stakeholders and meet changing planning scopes.

Project planning has to deal with environmental dynamics. Risks must be perceived before they become roadblocks. When risks arise, timely suggestions to reschedule the plan can help in dealing with the changes. Finally, a data-driven approach can increase transparency for more fact-based decision-making with less bias. Putting it all together will allow projects to be carried out in a good, fast, and economical way.

Where we come from

Classic planning methodologies usually start with the scope, which forms the basis for estimating work packages of varying size and complexity. The complexity may result from the number of people and companies involved, the interdependencies between activities, and the degree of freedom regarding the sequence in which tasks can be executed. Activities are often bundled into phases, which are not entirely distinct and offer limited transparency about the job to be done. In a large-scale project with a multimillion euro investment and a duration of several month to years, the early definition of work packages is a strong catalyst for discussion. The packages become manually aggregated to form a project plan split in phases with fixed milestones. Nowadays, classic approaches are increasingly combined with agile elements like sprints. However, the concept of sprints is frequently misused to cover project phases with a high degree of uncertainty.

Beyond the shortcomings of today's established methods, it is a misconception to believe that a construction project on the scale of building an airport can be entirely planned up front, taking into account every relevant aspect of the project. In reality, a plan created using the classic approach is outdate from day one. Its execution is mainly determined by firefighting to limit deviations to an acceptable level, with increasing inefficiencies. As Dwight D. Eisenhower once said: "Plans are worthless but planning is everything," which emphasizes that strict adherence to an original plan in constantly changing environments is not a good idea.[4] Doing so results in plans that, on one hand, are affected by delays, and on the other, do not profit from geared-up phases. The result are inefficient and unsuccessful projects.

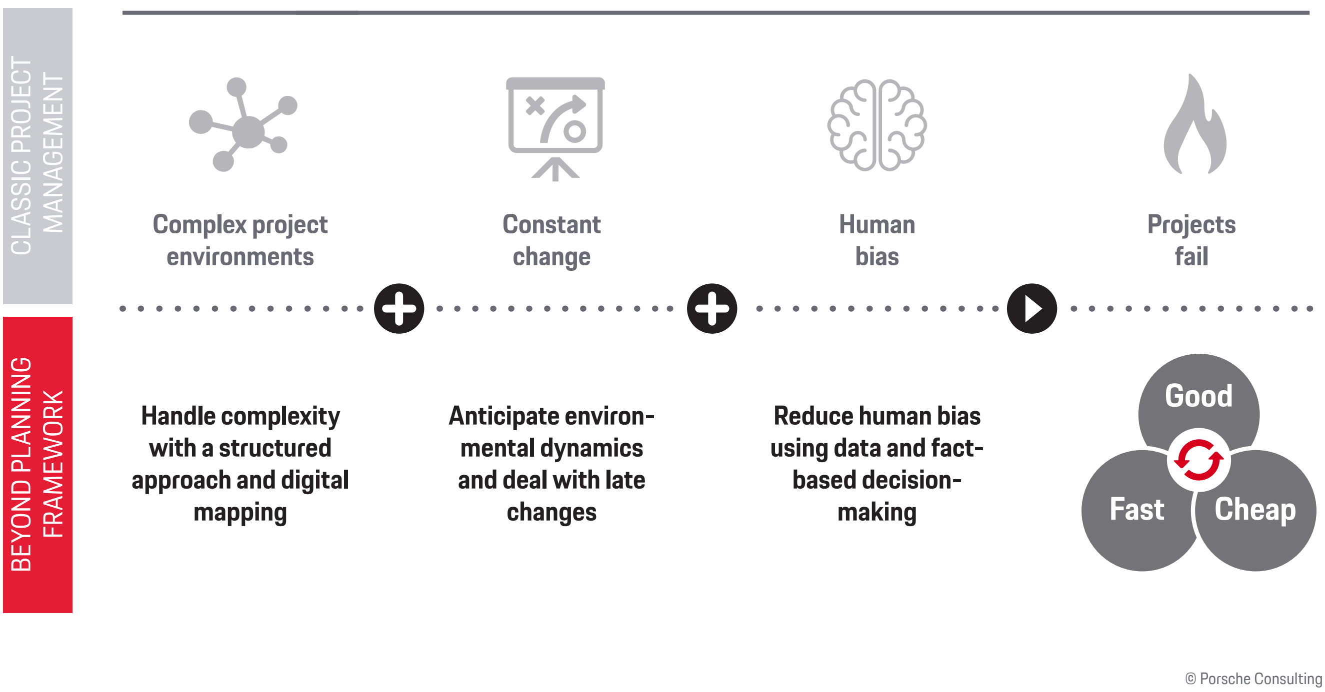

Fig 3. The Beyond Planning Framework approach for handling complexity, change and bias.

02 | The Beyond Planning Framework

Adequate methodology is crucial to planning large-scale projects. Today's dominant tools in planning departments, however, attempt to map the dynamic of an environment using static methodology. The Beyond Planning Framework offers a way to improve the odds of a smooth landing for large-scale projects. Its framework tackles inefficiencies by using a directed acyclic graph (DAG).

Instead of the classic top-down approach, a project plan is automatically generated and continuously updated based on detailed bottom-up data with a high level of granularity. All tasks affecting the overall project timeline are recorded with the relevant information for the later scheduling. The recording is a joint effort across organizational units and locations. With this in place, organizations can place significantly more focus on value-adding work instead of project planning. This could be completely carried out in a virtual environment by making use of online data sharing and collaboration tools. In other words, the clear focus on data makes a lot of centralized offline discussions obsolete while dealing with actual work, which has to be done anyhow.

Further, it is important to avoid concentrating solely on the operational execution; attention must also be given to indirect units. Otherwise, the DAG will seem like an alien element in the overall organization and thus be of limited value. For example, permissions might need to be granted to start working. In this case, it is not enough to add operational working steps to the DAG, the specific permissions and their timelines need to be added as well.

Hundreds of individual tasks are bundled to packages to maintain an overview. The packages are distinct and comparable regarding the individual size and complexity. As soon as all packages are in place, they are attributed further information to create links among them. In the framework, this is called the linking of attributed nodes (packages) with edges (connections) to each other. At a construction site, for example, one area comprising several jobs in one package might need to be finished before another can begin. The links and nodes together form the basis for the DAG and the calculation of the project plan (see figure 4).

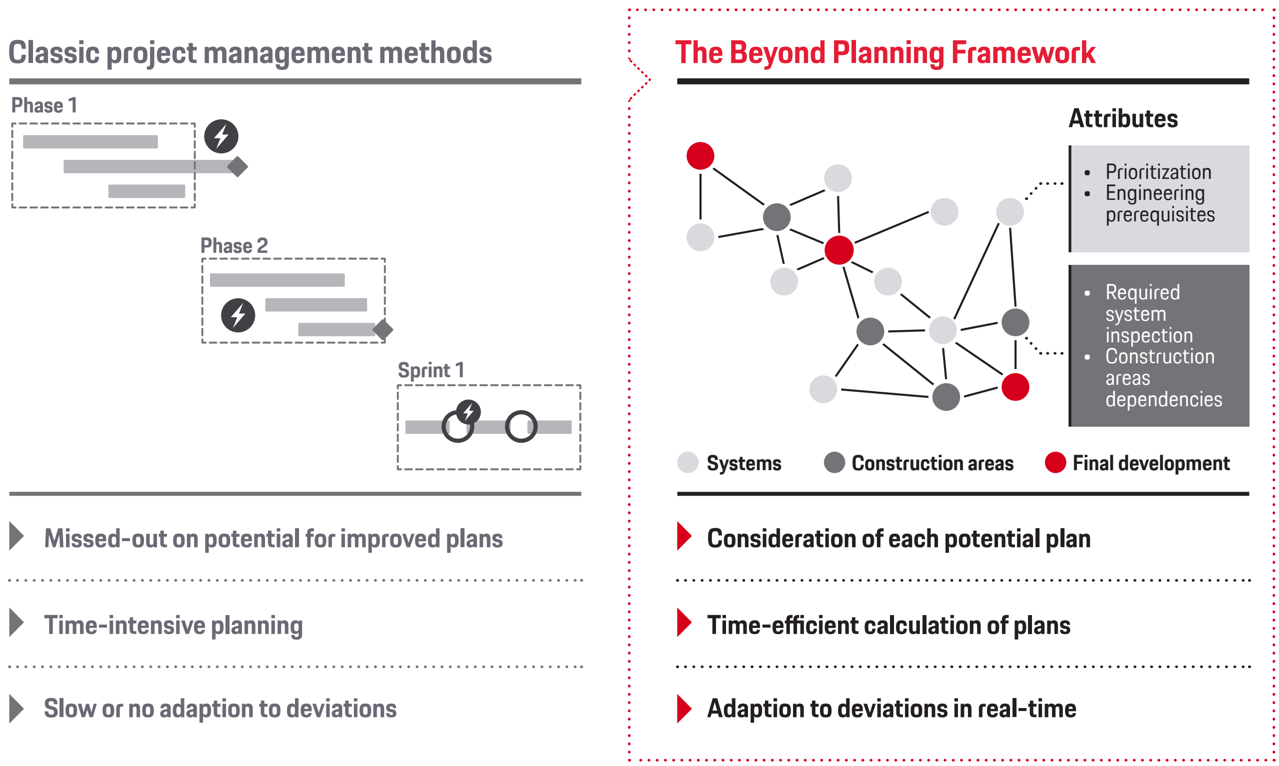

Fig 4. Comparison between classic project management and the Beyond Planning Framework.

Setting up the framework for large-scale projects is not child's play. The idea of transforming project plans into a graph model is new to almost any company.

There are four major premises to establish a new planning approach and Building the graph model:

//Create digital process map
The space in which the planning approach should operate has to be mapped in a digital process map.

//Define accurate and precise data
To span the graph each package has to be attributed with all relevant information. Building a graph model from inaccurate or imprecise data does not help much.

//Create objective function
The target needs to be clear. Weather it is a budget that must not be exceeded or a timeline, the target must be measureable in a digital format.

//Refine in an iterative manner
It is a fallacy to believe that an optimum can be found in a cloak-and-dagger operation. New data has to be continually recorded to render the model more precisely.

TRANSPARENCY AND TRUE CONTROL
The framework can provide sought-after clarity that is often lacking in projects. By introducing different planning levels, the framework is able to satisfy both the C-level's and the operative planner's desire for transparency. The new structure offers unprecedented visualization possibilities, thereby strengthening the analytical understanding of the planning problem. For example, most critical points can easily be ascertained in the project plan.

FLEXIBILITY AND ROBUSTNESS
Shedding light on the planning is only the first step. Lessons from the new-found transparency can be put into practice by directly adapting the graph. Packages can be manipulated without the usual lengthy search for the intended change in legacy planning software. Especially in large-scale projects with horizons of many years necessary changes in operations will be certain. This frees up time previously consumed by non-value-added tasks.

QUALITY AND TARGET ACHIEVEMENT
The increase in planning quality is at the core of the need to achieve greater robustness. This means creating a schedule that is feasible and less prone to being overhauled. Planning quality increases further as a result of the learning effect that comes from continuously generating data.

In some companies, a new planning approach initially takes more time to implement than an existing one. The framework front-loads necessary investments in the overall project. Organizations profit from newly created transparency, increased flexibility, and higher-quality planning (see figure 5).

These three levers reduce inefficiencies, resulting in shortened project durations and secured target achievement, reduced cost blocks, and freed up resources. In short: large-scale project planning always follows the most efficient project path, even if it is changing frequently

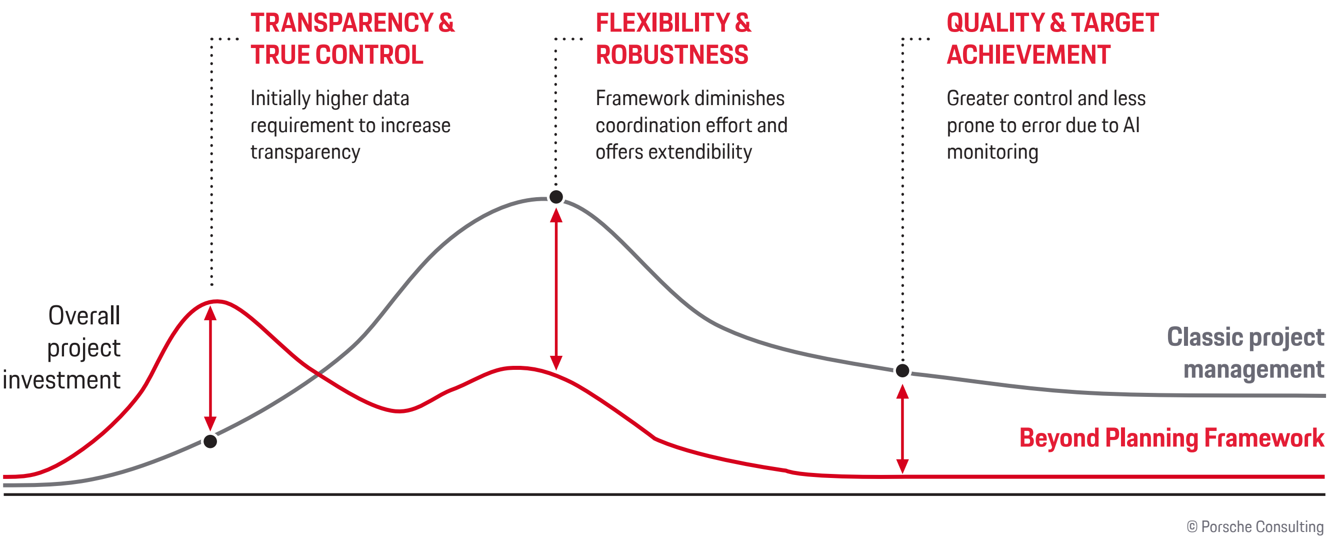

Fig 5. Project investment for classically managed projects compared with the Beyond Planning Framework.

Example of the Beyond Planning Framework: Building plants

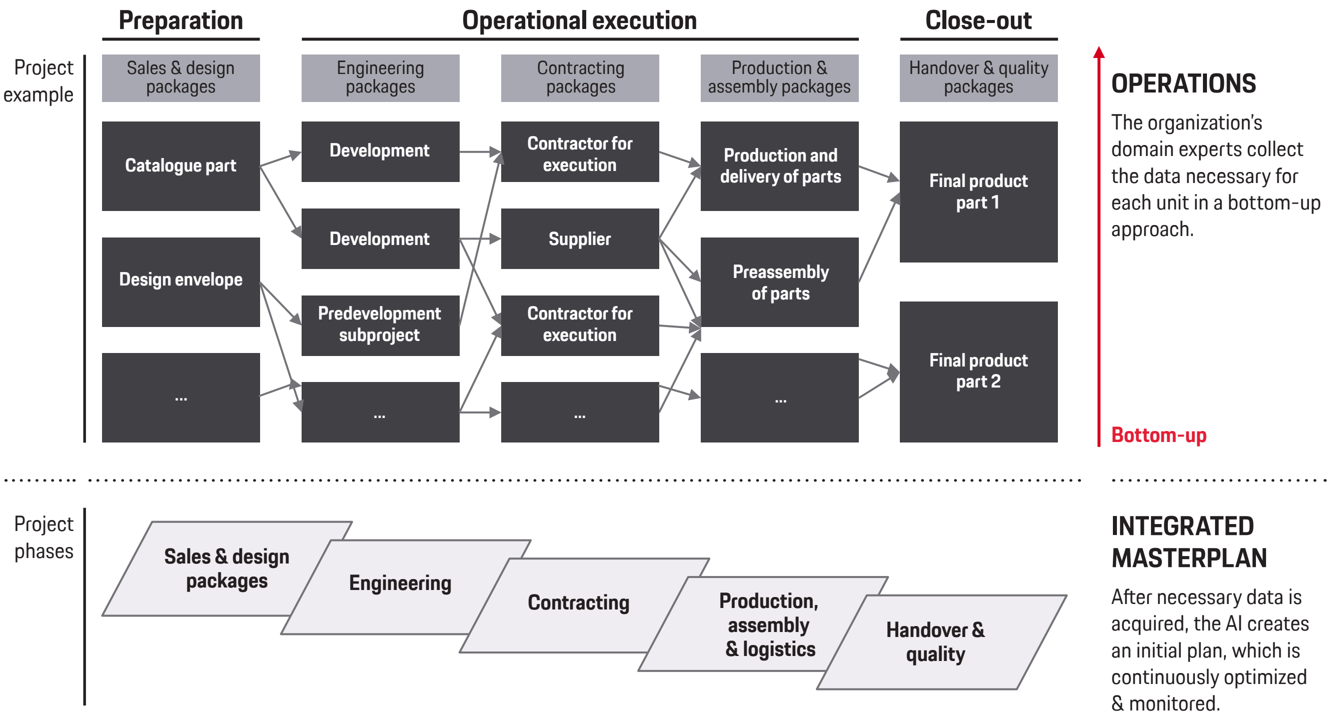

Fig 6. Example of the Beyond Planning Framework in action.

Figure 6 shows an example of packages used in the construction of power plants. The graph depicts packages and links for the phases of preparation (permissions), operational execution (systems, room areas, value stream), and close-out (final hand-over of plant areas). Together, they illustrate a model of optimized planning.

03 | How the Beyond Planning Framework Works

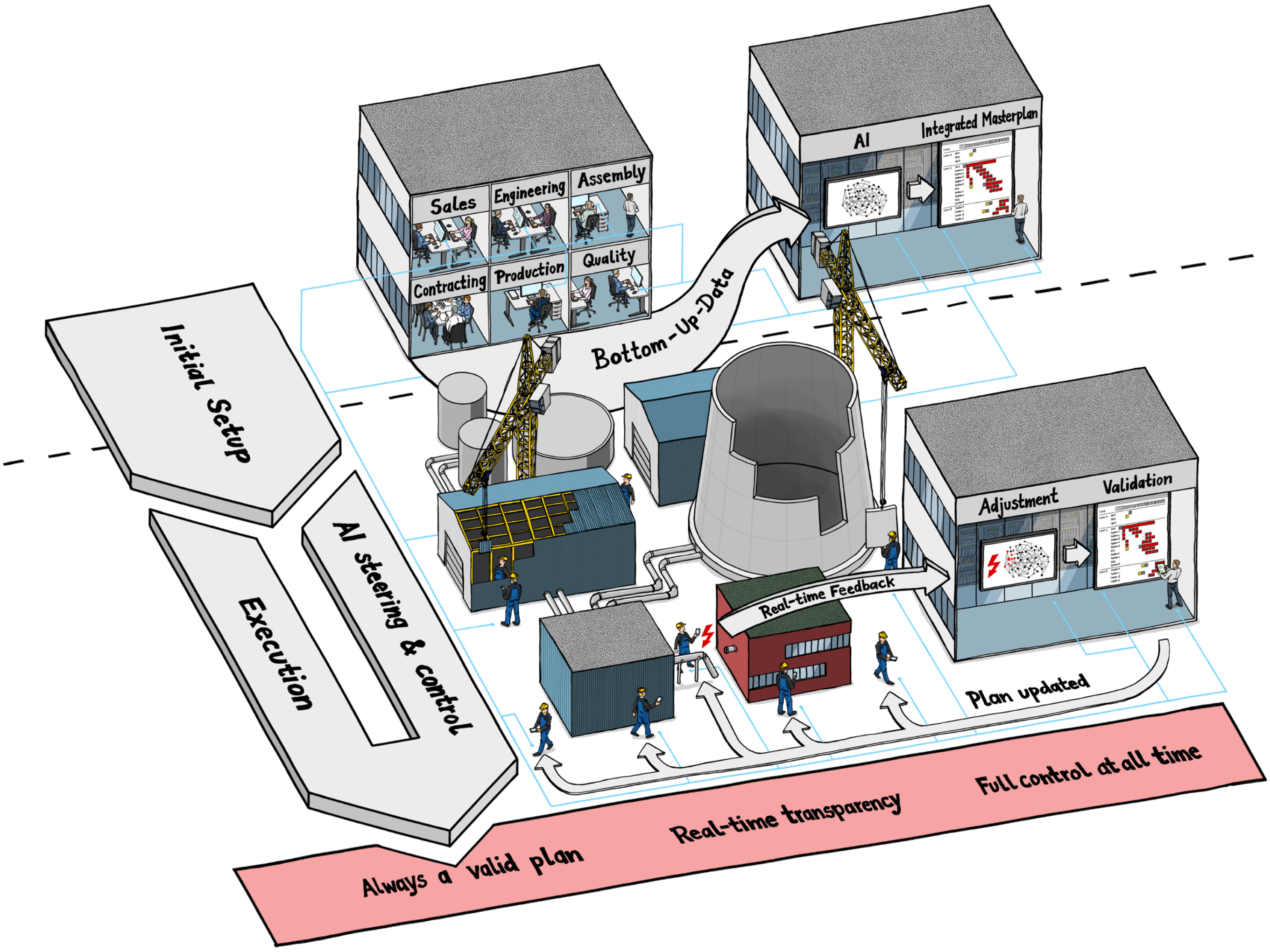

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Fig 7. Illustration of key elements of the Beyond Planning Framework.

Three steps have to be taken to anchor a new approach to the planning of large-scale projects:

First, the project path has to be cleared by the project manager, who defines the overall scope to apply the framework and set up the initial planning. Once all of the data is collected, the planning is entered into the AI system that calculates the integrated masterplan. The second step is the execution of the masterplan. A decentralized feedback system with smart devices is established to enable workers to report task-related information, such as the actual time or resources spent. This data is used for potential updates to the current plan. In the final step, the newly generated insights serve the AI system in its search for optimized plans. Any improvements are presented to the project manager, who decides with the domain experts whether to accept or decline the suggested modifications. The result is a plan that is always valid with regard to the current situation, is fully transparent, and offers users a high degree of control (see figure 7).

3.1 | Initial setup

In the initial setup, the project manager begins by defining the package types according to the activities and attribute sets that comprise them. The links between package types have to be defined in order to develop the graph model. The appropriate data is collected to flesh out the model.

Existing data sources are tapped first. For example, information on the production's cost structures for could be extracted using the enterprise resource planning (ERP) system. Second, if there is no data available for certain attributes, it is manually gathered in a bottom-up approach. One objective of this step is to aim for standardized attributes and package types, thus allowing many of them to be re-used in subsequent projects. In hazardous environments, or more generally, in situations in which a manual approach is not possible, a common method of enriching the database in the deep-learning era makes use of data from other domains. If there is no data, for example, on the amount of time it takes to install a certain type of valve in a power plant, data available from other domains can be used. Once the data is in place, the graph model is constructed. This process ensures an integrated plan that is not only the optimal fit for the objective function but less biased as well.

This graph model forms the starting point for calculating the integrated masterplan. The solution space for potential schedules grows enormously. It becomes so huge, in fact, a deterministic approach will fail to find the optimal plan in a reasonable amount of time. For example, if you have five tasks to complete, you end up with 120 different sequences to do so; 15 tasks results in a greater number of sequences than there are stars in the Milky Way. Inserting new constraints to reduce the solution space only creates the perception of control. Potentially improved plans are out of reach and the result is a mediocre plan. Moreover, a plan for a multiyear project has to be dynamically adjustable throughout the project duration.

In the face of such complexity, a generic AI-based search engine can be used to find the most efficient path in highly complex and uncertain environments. The smart search enables a time-efficient wandering through the solution space toward a global optimum while mastering local optima. The resulting solution is transformed into a project plan, also showing the familiar project phases. For the end user, the only visible change is in the data gathering. As soon as the package and links with the necessary data are available, the human side has completed its part of the equation. From there on out, the initial setup happens under the hood of the AI system.

AI and its underlying research fields are constantly evolving. New achievements range from financial market predictions to the reconstruction of speech from the human auditory cortex for brain-computer interface systems.[5|6] In recent years, reinforcement learning has been established as a stronghold of breakthroughs in machine learning, not least because of the popular example of AlphaGo (Zero).[7]

In general, reinforcement learning deals with the question of how agents should behave in an environment to maximize the cumulative reward or to minimize the respective cumulative loss. The game Go that AlphaGo (Zero) played and trumped its human opponent in is played on a board measuring 19 by 19 squares, resulting in the number of potential moves at a particular position nearly an order of magnitude higher than to chess. The winning deep reinforcement approach includes a Monte Carlo Tree Search (MCTS) for inference from trained deep neural networks. MCTS is essentially an algorithm that tries to predict at each state the next most-promising move. A node in the graph model is selected in four steps, then expanded based on a policy, after which a simulation is run until a terminal state is found. In the last step, the value of the selected note is updated by backpropagating the result.[8] That MCTS rolls out a huge number of possible graphs (with a focus on the most promising ones) to find the optimal path makes it especially valuable for search problems like schedule optimization.

This is nothing less than a paradigm shift. With the framework in place, organizations commit to skip doing project management for the sake of project management. There is no big planning department needed to create a project plan, because organizations have understood that this plan will only be valid for a very short time. All energy can be expended for work with actual work content; the project plan is just the result of AI optimization and can—or even must—change frequently while in execution.

3.2 | Execution

During the execution phase, the work force is constantly acquiring new knowledge. Tasks might be incorrectly planned or even hitherto unknown, and external stakeholders might thwart the plan by late deliveries or complications resulting from cross-functions, such as scaffolds. To profit from the acquired knowledge, it has to be digitally collected and stored in the correct form and at the right depth from the outset. The mixture of data granularity and simplicity in collecting it is of vital importance. If the interface is too difficult or time-consuming to interact with, the employees will not accept it. The devices have to be particularly reliable for hazardous environments. If an individual's performance is tracked, workers councils will not approve the feedback system. Using mobile devices with a user-friendly interface to collect anonymous data on tasks' actual complexity and required effort has turned out to have the greatest value. The data, collected in a decentralized way, is stored in a data lake within or outside of the company's IT system. The result is a data source for real-time data, which evolves to a continuous feedback system for the schedule.

The data must be acquired seamlessly, regardless of the approach taken. The scope of data collection must be in line with that of the project.

Beyond optimizing planning, this feedback system substantially drives efficiencies. It reduces the necessary capacities in operations to record the execution progress and eliminates the need for an intermediary that will forward and transform the gathered data for use in the planning departments.

//Preparation

In order to produce and assemble components to a final project result (e.g. a ship), a lot of ground work must be done, usually starting with sales and design. An area of great tension in most companies, sales departments are driven by ever-increasing expectations on the number of goods sold or flexibility until the end. To make this happen, salespeople are driven to make compromises, which which often empower customers to demand late design and technical changes. The design department has to find creative solutions for delivering the promised features. In addition, the shift toward customization and accelerated technology cycles result in products that are already outdated when commissioned. One example is the cabin design of the next generation of airplanes, defined years before the first plane takes off.

To handle such hurdles, packages in sales and design are equipped with specifications on the design freeze. For fast-evolving technologies like security systems, for which only an envelope curve exists, design freezes should be pushed back as far as possible. However, for catalogue components, such as those of a lighting system, the depicted package is attributed with an early design freeze, since late changes are unlikely and not beneficial. Standard parts like these might not need a design phase at all.

Permissions are often required to execute tasks. In engineering, technical permissions left out or not planned during the design phase cause frequent delays and can create painful workarounds. At the end of the design phase, engineering departments begin discussing among themselves the path to realizing the design. In 2019 the world's 50 leading organizations invested around 12 percent of their annual revenue in R&D to drive innovation and maintain their position at the forefront of their industries.[9] In the long run, over-engineered products are doomed to become shelf-warmers. Products may become too complex and costly, resulting in missed deadlines and a negative ROI.

To increase transparency, each engineering module is compromised in a package. Whereas off-the-shelf modules only need technical validation, modules for advanced tech products require more engineering. They may need technology qualification, system engineering, detailed engineering, or an application step. The package can therefore be classified by the degree of novelty in order to create individual timelines that match reality (see figure 8).

In our integrated economy, large-scale projects easily involve hundreds of external stakeholders. Companies make use of suppliers for reasons of limited resources or flexibility. Successfully managing the interplay among suppliers is crucial and starts with the contracting. It often becomes clear during execution that the ordering company and the contractor have different understandings of the committed content and scope. In contracting, packages are the objects offered to a potential tenderer. Packages describe the service to be performed and the amount of work needed to perform it. They are therefore attributed with the complexity and effort associated with the tasks. Packages are offered to multiple tenderers to create a pool of tenderers, providing adequate capacity and flexibility for demand allocation. In addition, they can serve as building blocks for outline agreements with individual tenderers. For example, the tasks needed to tear down certain equipment—including the amount of work performed in each step—comprise a package that is offered to potential contractors.

//Operational execution

Objects not outsourced to external parties are realized in operations. Engines are made on production lines and cooling systems assembled at the point of later use. Productions and assemblies are often characterized by fixed sequences in which tasks are executed. Indeed, there are tasks that must follow a strict order. Potential degrees of freedom are squandered, however, and the rigidity can become painful at times. Failure in a certain production step, for example, may bring the whole line to a halt, resulting in underutilized capacities. By stepping away from fixed production lines, the number of potentially improved schedules increases tremendously. In this setup, objects are no longer produced on fixed lines but on production islands to which objects are routed, swarm-like, with individually adjusted process steps and step sequences.

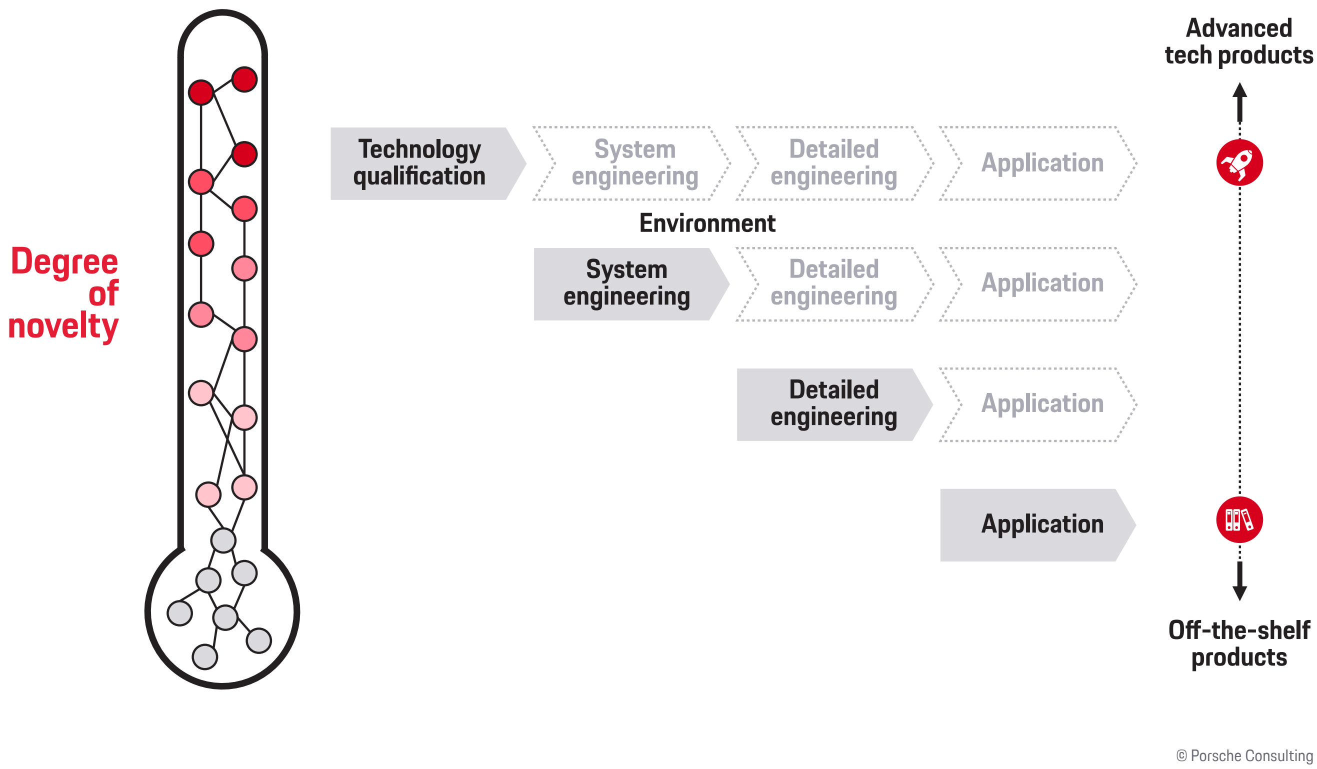

Fig 8. Different timelines for engineering phase depending on degree of novelty.

Packages in operations represent the different objects to be produced and assembled on the line. A package lists all tasks needed to bring the object to the finish line. In the cost-sensitive environment of production, there is particular focus on efficiency. Hence, the tasks are attributed with the resources (FTE and machines) and time (for waiting, set-up, value-adding, and transportation). Side constraints like working hours per day, maximum machine throughputs, or production process characteristics like minimum layover times are added. Together this eliminates the risk that resources will not be available to or accessed by various parties simultaneously due to failures in production and assembly plans. Linking the packages considers that some production steps might have to be carried out together, adhere to a certain pattern, or have other dependencies. Receiving real-time feedback on actual duration during execution is crucial to being able to judge whether the project is still on course.

//Close-Out

The most efficient operation is of limited value if quality gates are not passed. To minimize quality-related extra costs and time, sources of failure must be discovered and analyzed and steps initiated to prevent it from becoming a chronic issue. Quality control is a double-edged sword. If controls are extreme, the additional costs do not pay out, whereas lax controls result in unsatisfying project results and a shrinking customer base in the long run.

Each individual quality control corresponds to one package. The packages aggregate the individual steps of quality control, the acceptance criteria, and the resources required to complete it. Information on certain requirements regarding the sequence or certain fall-back options are stored in the links between the packages to build the graph model. As with preparation and operations, the objective of optimization defines the attributes and the links between the packages. Together with the packages from operations, they generate a holistic view of the manufacturing processes. The structured approach abolishes ad-hoc initiatives and lifts the quality level.

3.3 | AI-driven control

The data collected in the initial setup and execution must be fed into the AI system on a continual basis; otherwise a data leech of limited value is created. By adding new data to the model, the results from the AI system are continuously adapted. For example, if a certain task often takes longer than initially planned, the system might recommend increasing capacity. That might lead to situations in which the AI system suggests a change to the plan even before the reasons are visible. To turn the changes into reality, the suggestions are reviewed. A decentralized expert group decides on the recommendations in (virtual) conferences by examining the simulation results. The effect is an additional layer of quality control and a way to nudge toward greater acceptance of the results. This is not a one-way street, however. The planner with decades of domain expertise might want to test different scenarios, for instance, removing the restriction of fixed resources and applying ranges to each task instead. This opens up a vast number of new, potentially improved schedules. Simulating scenarios offers insight into how the levers behave. This is called collaborative intelligence, since it merges the benefits of machines' computational power and man's knowledge and experience. As soon as there is an agreement on a change to the overall project plan, the plan is updated and passed back to execution—without any manual work at all.

04 | The Importance of Change Management

Relying on a computer-generated plan might sound scary to some people. Jobs made redundant by computers is a fear familiar to those in the industry. The Beyond Planning Framework enables human competence to be reallocated and used in the most value-adding way, which is usually not project management.

Human expertise is thus more important than ever. Not only in the development of the graph model but in its execution. In continuous AI control, it is the domain expert who decides on adaptions to the plan. Without the human skill set of creativity, critical thinking, and dealing with ambiguous information, potential schedules would lack an important component. Trust in the framework and the AI system is needed for the project manager to be able to act as a quality gate. From the outset, employees must be included in defining the overall objective function. For example, optimizing a plan's duration might be preferable to a pure cost objective because specific permissions expire at a certain point in time. The data collected for this objective is stored in a database provided and owned by the organization. Data privacy is ensured by only gathering anonymous information about the content and complexity of tasks.

Work principles—including individual benefits—must be outlined in repeated training cycles. Understanding can be sharpened, for example, by making use of prototypes in a protected environment and simulating scenarios. Such personal experience is essential to a successful learning experience. Afterwards, the project member can act as multiplier for the organization and communicate the purpose of modifications to the planning and execution of large-scale projects.

The management team has to lead this transformative journey by example and act as role models. A wide range of studies point out the importance of top management when adopting new technologies within the company and promoting their application. Showing commitment and fostering the use of AI by acting as a pioneer are a key factors that can dispel potential reservations in the workforce and have major impact on achieving the desired change in employee behavior.

05 | Getting Started

In today's rapidly changing world, large-scale projects seem like a relict from the past. Indeed, they are often unable to meet expectations. Although reasons vary from case to case, the underlying challenges remain the same. The Beyond Planning Framework offers a way to overcome these challenges.

For companies, it represents more than an evolutionary change to how large-scale projects are planned and carried out. What is new is the combination of methodologies and technologies from foreign domains to improve the planning process and projects as a whole.

Understanding and appreciating these principles makes existing planning approaches look outdated or even negligent. Those organizations that successfully apply the principles profit from increased transparency, higher degrees of flexibility, and improved planning quality overall.

COMPANIES SHOULD HAVE THREE PRINCIPLES IN MIND

A

Don't underestimate the importance of data

Large high-quality data sets with relevance to the planning object are essential if correctly utilized. The granular collection has to be done in a bottom-up approach to end the rule of thumb planning and misaligning of resources.

B

Don't try to handle complexity manually

Planning problems increases exponentially with the size and scope. Adding only one additional layer of subcontractor adds a whole new complexity. Turning the heavy lifting to industry proven algorithms is the smart way of handling it.

C

Don't do plans. Do work and trust the AI

The environment is of too much of dynamics to be completely foreseeable. Searching for the one all-weather plan is a waste of time. Focusing on work and feeding an AI with updates as soon as they are known leads to better and more reliable project plans.

Fig 9. Principles for project management in the age of AI.

Getting started with the Beyond Planning Framework

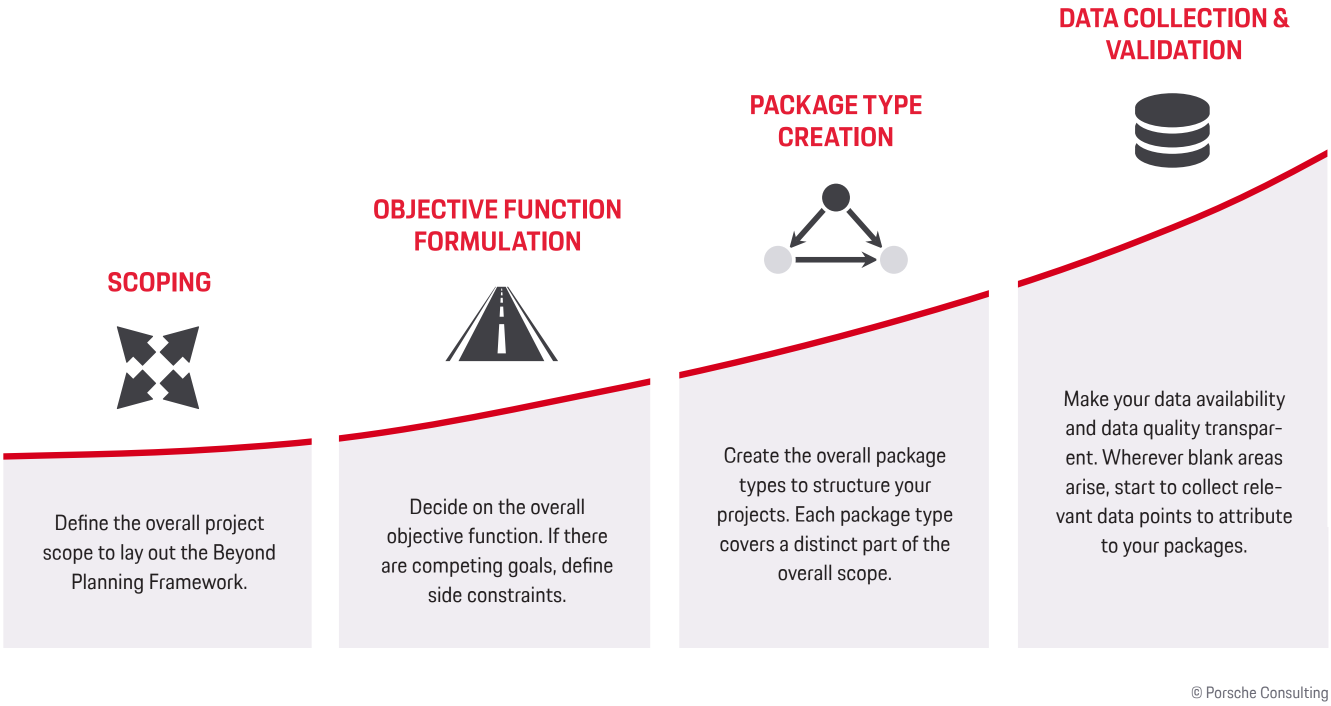

Fig 10. Four steps for starting with the Beyond Planning Framework.

Each transformation comes at a cost, however. This new way of working must be learned continuously to become the new standard. After all, people are still essential—for providing the domain expertise during the initial setup, offering feedback to the system during execution, and reviewing the AI's suggestions during monitoring. Getting started with the framework require defining the project scope, formulating the objective function, creating package types, and collecting and validating data (see figure 10).

Taking these steps will increase the awareness for the ways in which a more data-driven approach can improve project planning and control. Organizations will see that harnessing the methodology and technology can fundamentally help meet set deadlines, reach cost targets, and generate more sustainable results—and once again make the execution of large-scale projects a success story.

IN BRIEF

01 Uncertainties in large-scale projects are ubiquitous and cannot be disbanded. Smart project management is key to dealing with them.

02 The Beyond Planning Framework combines human domain expertise and artificial intelligence as an alternative to manual or static planning approaches.

03 The Beyond Planning Framework starts by defining the overall graph structure and gathering relevant data in a bottom-up approach.

04 The heavy lifting of calculation is taken over by a deep-learning engine, which ensures a valid and optimal schedule at all times.

05 Real-time feedback during project execution feeds the AI engine and is key to secure target achievement and optimal project results.

Appendix

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Acknowledgements

The authors would like to thank contributors Christian Bücker, Christoph Fritsch, Dr. Carolin Hermann, Robin Hermann, Hans-Henning-Källner, Artur Korinski, Sarah Pannes, Marc Piller, Benedikt Senger and Michael Schilling.

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