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GENERAL CONSTRUCTION

Bachelor thesis

Project Control applied on a pilot project: A cost and time analysis

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Abstract

Controlling cost and time are fundamental for any construction project. Those projects face unforeseen risks, such as equipment breakdown or rarer events, which indirectly impact them. Moreover, construction projects are usually a "one-off" design involving multiple stakeholders which adds to their uncertainty and complexity. Thus, effective project control tools controlling both current and future cost and time are important to manage projects and to reduce risk of delay and/or cost overrun at project completion.
There are several methods to realize project's cost and schedule control and forecasts. However, most of these methods are more or less complex or might require deeper knowledge or cost and time investment. This paper proposes a design of an easy tool for General Construction co (GCC), an engineering and construction company, based in Mauritius. The research aimed to develop a tool that would support existing controlling tools of the company. The Technical Action Research (TAR) methodology was followed. It involved the use of a residential construction project. The case study was used to provide data as input to the tool and to validate it. Moreover, unstructured interviews were done with the project manager and the quantity surveyor of the case study. The interaction allowed to design a project control tool that answers the project manager's requirements. The tool provides indication of current project performance but it also forecasts expenses, revenues and profit. It gives easy and accessible forecasts, which can be adapted and modified if necessary to fit better a project manager's need. A guideline to use the tool in practice was also given in addition to a discussion on the results obtained from the case study. The tool presented some challenges, such as forecasts, thus, recommendations in order to improve some of its design features in further research are provided in this study.

Keywords: Project control, cost, schedule, forecast, KPI, case study

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List of acronyms

GCC General Construction co

MP Magenta Parkside

TC Transinvest Construction

QS Quantity Surveyor

CSFs Critical Success Factors

CPM Critical Path Method

PERT Program Evaluation and Review Technique

EVM Earned Value Management

PV Planned value

AC Actual Cost

EV Earned Value

KPI Key Performance Indicators

TAR Technical Action Research

FAST Functional Analysis System Technique

SMART Specific, Measurable, Acceptable, Realistic, Time-related

BIM Building Information Management

1 Introduction

1.1 Research background

The main characteristics that differentiate the construction industry to other sectors are linked to its product. Civil infrastructures are a functional and cultural necessity, they last a long time and involve significant investment, financially and ecologically. The time that projects require and their size, often makes them be the main source of annual income for a construction company. Projects are the result of client requirements and thus, each of them is often a "one-off" design which adds to the complexity to deliver a successful product. Thus, each decision made during the project design and its construction have an impact on the company itself but also on society in general (Cole, n.d.; Williams, 2015).

The construction industry involves a considerable amount of money where projects are developed for a client which means that the predefined agreement with the client to finish the project on schedule, within budget and with the projects requirements must be answered accordingly. This is known as one of the well-known success criteria measure, the "Iron Triangle" where quality, cost and time are the main criteria for successful projects (Bojan et al., 2014). If this threefold criterion success has been widely used as a standard criterion for decades, by the late 1980's a broader definition appeared including both the success of the project output and the success of the management of the project ("Iron Triangle") (Mbugua et al., 1999; Williams, 2015). However, those criteria did not include the increasing need for projects to be more sustainable for the environment and for society. Consequently, project success was then characterized by different measures for instance, by the U.S. Agency for International Development and the United Nations , success was characterized in five ways: (1) efficiency; (2) effectiveness; (3) relevance; (4) impact; and (5) sustainability (Williams, 2015).
Hence, there are financial and non-financial factors that influence the performance of construction businesses to meet the defined goals of projects such as the "Iron Triangle" criteria. The Critical Success Factors (CSFs) for a project are the few which are fundamental to a successful result. The CSFs differs depending on the project, people or project factors are an example of categories to consider (Gunduz & Almuajebh, 2020; Mbugua et al., 1999).

The success of the project, depends highly on the project management as it is connected to several CSFs. Both the success of the project output and the success of the management of the project depends on the management of the project. The last one which includes the "Iron Triangle" criteria, generally falls under the responsibility of project managers. However, it is a complex task due to the nature of the construction industry and to its uncertainties. It makes it complicated in practice to predict costs and time while balancing it with quality production (Bojan et al., 2014; Y. A. Olawale & Sun, 2010; Phaniraj & Srinivasan, n.d.).Those three criteria are interrelated so a change in one influences the others. It involves constant progress analysis but also trade-offs among those criteria during the project implementation. In fact, the recent events caused unforeseeable risks such as the COVID crisis or the Ukrainian war, they caused uncertainty, time delays in construction projects but also rise in life cost such as price increase in fuel and importations which led to tensions in many countries. Other issues are not subject to events occurring worldwide but directly to the technical or labour issues such as the lack of skilled workforce or communication issues with the client (Mbugua et al., 1999).However, it is more accurate to think of those problems as independent problems that interact together.Moreover, construction projects involve interaction and collaboration between multiple parties such as local authorities, engineers, environment and cost consultants, suppliers, architects, contractors and sub-contractors and not to mention the client. The uncertainties in the construction industry imply that construction projects usually have to do corrective actions like reschedule or change in material choices to ensure that the CSFs of the project are met (Mbugua et al., 1999; Y. A. Olawale & Sun, 2010). Hence, if there is a difference between the planning and the actual activities performed, there is a need to update the performance in case of delay to ensure that the future performance meet the initial expectations (Phaniraj & Srinivasan, n.d.).
Project Management includes different sub-functions where it involves the management of people, processes and results of a project. The main aim of project management is to make sure that a successful project is delivered. It is focused on quality, scope, cost and schedule. One of the main tool of project management, is project control which is a sub-function, only focused on project cost and schedule with the related planning, monitoring, controlling, communication and forecasting outcomes (Y. Olawale & Sun, 2015). A definition given by Y. Olawale and Sun (2015) coming from the Association for project management is: *"the application*

of processes to measure project performance against the project plan, to enable variances, to be identified and corrected, so that project objectives are achieved". Hence, project control main goal is to analyse and gather project data to decrease the variance between costs and schedule from what was planned before the project implementation, hence the objective is to improve the project performance if the forecasted performance is not acceptable.
Project controls are part of a process. It is complex and iterative due to its occurrence in different life cycle phases of the project. Hence, five phases usually consist of the project control process, the figure 1 displays those different phases (Skripak et al., 2019).

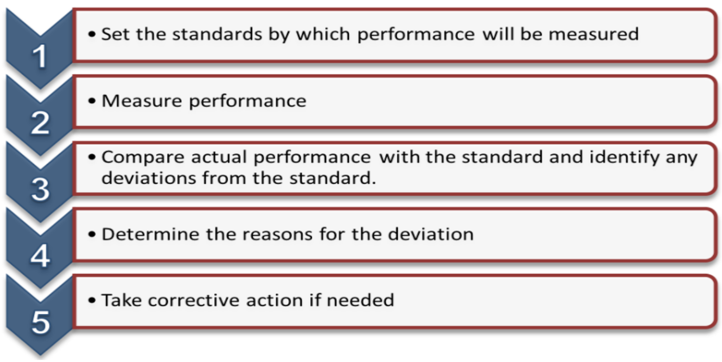


Figure 1: Project control phases (Skripak et al., 2019)

The first three phases are essential as they are the core of project control. Without those phases, the deviations from the plan would not be known, thus, no corrective actions would be taken. The first stage consists of planning the work to be done, the budget to be spend and how long the tasks should last according to the plan. Then, the actual performance of the project must be analyzed. The planned performance must then be compared to the actual performance. It allows to see any deviations from the planning. Moreover, it is necessary to forecast the future costs and time associated with each project's categories such as labour. In fact, forecasting permits to visualize how the actual performance of the project will impact the end result in terms of both cost and schedule (Y. A. Olawale & Sun, 2010).
It is important to have an effective project control in construction projects to improve project performance and decrease the probability of project failure due to the influence of uncertainties which is more present than in other type of projects (Changali et al., 2015; Y. Olawale & Sun, 2015). According to Changali et al. (2015), 98% of megaprojects (more than billion dollars) are subject to cost overruns or delays. Such projects are in average delayed by 20 months (Changali et al., 2015). Moreover, another study from KPMG (2015), revealed that only 31% of construction projects were executed within 10% of the budget and only 25% were completed within 10% of their original schedule.

1.2 Problem statement

Construction projects play a main role in building necessary infrastructure in economic growth (Ameri Shahrabi & Mohammadi, 2013). According to a study of Ameri Shahrabi and Mohammadi (2013), a delay in one construction project can harm other related projects and thus, the whole economy. Therefore, for project managers, it is necessary to know the impact of factors that create delay in a construction project and how to reduce the related costs by predicting the project timeline and costs. Many studies identified the causes of delays and cost overruns revealing various but often similar issues such as a poor change control which has been identified as a major cause of cost and time overrun. Moreover, it appears that most of those factors occur during the construction phase of the project (Ismail et al., 2013).

Project control methods already exist and are used by construction companies to alert them about cost and time overrun such as Gantt charts, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT). Those methods are supported by software like Microsoft Project or Asta Power Project

(Y. Olawale & Sun, 2013). However, even if they are widely used, these still do not always obliterate time delays and costs overruns in many projects (Y. A. Olawale & Sun, 2010). One of the reasons could be that although those methods are used to help to alert the user, they still require a great risk management to mitigate issues and reducing their impact on the schedule and the budget.
Despite the existence of numerous studies on the importance of project control and on methods that can be used, there is a lack of studies on specific project control tools to apply those methods effectively and to improve the project control in practice (Hoffman et al., 2007; Y. Olawale & Sun, 2013; Terry & Lucko, 2012). Studies had focused on the project planning process instead of on the control process during the project construction (Y. Olawale & Sun, 2013). A common motivation from past studies was the desire to make project control models easier to use in practice. However, many studies emphasised the need for a comprehensive model to predict better the performance of construction projects as studies revealed that tools of project control are still not providing information in an integrative and effective way to combine current and forecast project financial monitoring and time (Hoffman et al., 2007; Leon et al., 2018; Terry & Lucko, 2012).
Furthermore, the control tools are generally being used after issues occur in a project because they do not address effectively project controls and they appear to differ amongst construction managers (Baban et al., 2020). Due to the dynamism of construction projects and their one-off design, the need to integrate such dynamic characteristics in project control and monitoring is crucial. However, Y. Olawale and Sun (2015) stated that according to some researchers, those characteristics were not sufficiently considered and there is a need for integration. In recent years, Building Information Management (BIM) appeared as one of the alternatives to control projects. Using BIM tools could allow to save money and time but also to reduce waste of materials while improving the communication between stakeholders. For project cost and time control, one of the BIM technology used is called the 4D CAD which combines 3D models and schedule. However, using such a method can be time consuming when it is not already in place so that a transition is required (Eastman et al., 2008).

With the absence of a tool to adopt easily project control through the execution of the project which integrates actual and forecasted schedule and cost information this constitutes a gap in research towards predicting and improving construction processes and projects' performance.

This research is carried out for a host company, GCC, which is among the leading construction, engineering and project management companies based in Mauritius. If a delay occurs in any project of GCC and other construction companies, it will be costly, as each day of delay would cost the company due to the contract agreement with the client. GCC, however, does not have a proper project control tool to forecast the costs, progress (revenue) and delays of projects. Currently, the progress, delays and related cost are only given at a moment of time t0. Some predictions can be done but they are time consuming and it is not efficient for the project manager to analyse the data to draw conclusions for revenue predictions. The variance between the revenue related to all the tasks (earthworks, roadworks, drainage...), the budget which will occur in the future and the profit margin, are currently not available to the project manager. Hence, the research is needed to provide a solution to this issue due to the great importance of project control in a project. The company is currently looking for a way to reduce unforeseen delays and costs by predicting them but also to forecast the project profit based on the current project performance. Additionally, the labor and materials generally involve the most significant amount of money for the company and the labour also has a risk of cost overrun and delay. Hence, there is a wish to monitor especially those elements. Thus, this research fits in with the company's objective and it will take the form of a Technical Action Research TAR (see section 4).

Therefore, this research fills this knowledge gap by developing an effective digital tool for a successful project control by using a real case, the Magenta Parkside (MP) project, as a case providing background and support to the research. GCC acts as a contractor in the MP project, which is a typical project of construction where there is a risk of cost and time overrun. Thus, this study is based on a pilot project, the MP to design, test and evaluate a project control tool which must be fast, affordable and easy to use and to understand by project managers of GCC. The tool must provide actual and forecasted performance indicators combining both cost and time.

2 Research aim and questions

2.1 Goal and objectives

The research aim is to help project manager's of GCC to predict the cost and time at completion of a construction project and for each of its tasks such as earthworks and roadworks. Moreover, the research also aims to help to evaluate the project progress during its construction phase by using the MP project as a pilot project. It will support project managers of GCC to control and manage the project for it to finish on time within budget and if not to give the possibility to alert stakeholders of potential cost overruns and delays.

The research objectives are to (1) develop a tool fast, cost efficient and easy to use by project managers of GCC, to give actual and forecasted project time and cost and include key performance indicators which would support the other project control tools currently being used, (2) test and evaluate the efficiency of the tool on a real life project, (3) provide insight on challenges of using the tool, and (4) analyse the results to give an output on the performance to project managers on the MP project.

The project control objectives are (1) to set the standard cost, progress and time performance of the project, (2) measure the actual project performance, (3) compare the actual performance to the planned performance and (4) to forecast the performance at project completion and (5) compare the forecasts to the planned performance.

2.2 Research

The resulting questions of the research are displayed below. The first main question represents the knowledge question of this research while the second one is there to solve the host company problem. Moreover, to structure the research better, sub-questions are formulated.

1. What are the design requirements for an effective and cost efficient tool that could add support to the already existing project control tools of GCC to predict the cost and time during and at completion of a project?
   - What are the requirements and criteria that a project control tool must satisfy to be effective and successful to forecast more accurately the performance of a construction project for project managers at GCC?
   - How should the tool be used in practice by other project managers at GCC?
2. What will be the actual and forecasted performance indicators and the profit margin of the MP project for the overall project and for the labour and materials control resulting from the tool's result analysis?
   - What recommendations can be given to the Project manager of the MP project concerning the results of the project control analysis obtained through the developed tool?
   - What are the challenges to apply the tool on the MP project?

2.3 Significance of study

This study allows to identify the current and forecasted delays, revenues and cost overruns of the company in the pilot project, MP, but it can be extended to other construction projects of similar complexity and size. The outcome of this research will allow the project management team to identify factors of risks to react accordingly and prevent unwanted results. The tool will also assist project managers in preparing a new schedule in case of delay.

2.4 Scope

The research will be focused on the pilot project: MP and the analysis will not be extended to other projects. The analysis of the results obtained thanks to the tool will be mainly focused on labor and materials analysis as those involve the most significant amount of money but also in the case of labour, a risk of cost overrun and delay. The tool will only contain tasks related to the preparation of land of a residential area. Hence, tasks such as roadwork, earthwork but it could be easily extended to other tasks if required for another type of construction project. The tool will be focused on the construction phase of the project life cycle where the major part of the project work takes place (execution of project plan, communication between stakeholders, project control). Factors of cost and time overruns will not be studied again as enough study was done on the topic. Furthermore, the case study analysis for GCC will only include the steps one to three of the project control phases discussed previously (refer to section 1.1), the determination of the reasons for the deviations are not included in the research as well as the corrective actions required. This means that the tool will not include the risk management. However, recommendations are given according to the results obtained on the possible reasons for deviations. Furthermore, this study does not tend to find a new forecasting method but to adapt current methods to support project manager's of GCC.

3 Literature review

In this section, a literature review is done to present existing project control tools used to forecast and to control project's cost and schedule. The literature review will help to choose an adapted forecasting and control method for the study. The requirements for an optimized and more efficient tool are given to design the tool with the desirable characteristics and performance indicators.

3.1 Project control methods

Various research attempted to predict construction project performance through different modelling methods and strategies. As mentioned earlier methods such as Earned Value Management (EVM) and CPM are supported by softwares like Primavera or Microsoft Project but also with BIM tools.

Tools and framework to forecast project performance are being developed by the use of multiple project cases.This is usually done in those research to create performance indices. According to Assaad et al. (2020), multiple linear regressions and Markov chain models have been used to predict possible deviations in project schedule and progress predictions.
Forecasting with regression models could consist of linear forecasts or multiple linear forecasts. Both assume that a time series (e.g.cumulative cost) has a linear relationship with other time series. The difference between both is that multiple linear forecasts would use multiple regressors and coefficients.
In cases where there is no linear relationship, quadratic or higher order trend can provide better fitting. However, those provide unrealistic results once they are extrapolated. Thus, an alternative is to use a piecewise linear trend that will bend at some point in time to fit the data. Piecewise cubics could be use as an alternative to provide better results than the linear piecewise trend but when the data does not stay within the historical data range, the forecasts become unreliable. Another possibility is to do some data transformations on the regressor of the forecast variable such as the logarithm to enable the data to fit better the trend and then do a forecast.
The Markov chain, on the other hand, uses the assumption that the probability of observing a value is only dependent on a very small amount of recent observations. Hence, the predictions are done without looking too far in the past. More complex methods have also been used by researchers such as Leon et al. (2018), who proposed a model based on 8 indices by using a system dynamics. Or models using the artificial neural networks used to predict project performance (Assaad et al., 2020).
The uncertainty and risks of projects and their one off design nature creates a need to incorporate uncertainty in methods. This is usually done by using stochastic networks where cost and schedule are following probability distribution and are not deterministic. However, the EVM method assumes certainty so project managers know if there is a cost or time overrun or if the project goes better than planned. This can mean that even if the project is delayed from planned values obtained through methods like CPM or PERT, it can still stay in an acceptable range of delays when the uncertainty is taken into account (Acebes et al., 2014). As discussed earlier, there are multiple project control tools and methods that can assist in keeping a project on track where they do include both cost and time. However, some methods are more common and are being used widely. This is the case of the EVM which is widely applied as it is relatively easy to apply and as it integrates the objective, time and cost control under the same method. Three measures are used: the budgeted cost for work scheduled also called Planned value (PV), the actual cost for work performed or

Actual Cost (AC) and finally, the budgeted cost for work performed or Earned Value (EV). It is applied to manage and forecast predictive performance on a project (Acebes et al., 2014; Vanhoucke, 2013).
However, traditional EVM have some lacks that could lead to inaccurate results. Cost factors and monetary based indices for measuring the schedule performance of a project are the most important shortcomings of the traditional EVM methods. To improve the performance of the original EVM method, stochastic S-curves were also applied to have project predictions and to include the variability of construction project (Acebes et al., 2014). Moreover, fuzzy approaches which are used to solve problems which are related to uncertainty or vagueness, are incorporated to stochastic approach. Furthermore, control charts to monitor project performance data have also been added to such methods and researchers also gave a log transformation method to monitor the earned value indexes (Acebes et al., 2014). As mentioned previously, in the traditional EVM, in the planned value or earned duration method, there might be unreliable or biased results to forecast the final duration of the project. One method has been developed to overcome this issue which is the earned schedule where it provides more accurate forecast, thanks to another index: the Schedule Performance index (SPI(t)) (Vanhoucke, 2013).
Furthermore, Assaad et al. (2020), also mentioned the use of a change point analysis to estimate the final cost and the duration of projects with the use of cost and time indices. According to Mortaji et al. (2014), this analysis allows to identify the actual time and reasons of change in a project performance by providing more accurate results than EVM as it estimates the project final cost and duration by only considering the latest periods in which the performance level of the project is stable.

BIM is being used widely as a transition from the conventional approach to design and manage a project through its entire life-cycle. Instead of having multiple platforms, BIM allows to present virtually a project physically and functionally during its life-cycle which gives the possibility to exchange information between stakeholders in one model. In fact, it allows to combine two to five dimensional design, where there is an integration of parametric design models, scheduling and cost which can consist for example of generating bills of quantities and estimate labour costs. Even though, BIM is commonly used for collaboration, it is rarely used for estimating and scheduling as it involves cost and time to create the model (Franco et al., 2015).
For project control it is generally used prior to the construction to save both time and cost while reducing waste. BIM appears to be relatively reliable as it gives more accuracy to the Quantity Surveyor (QS) estimations to do cost estimation of a project, as it quantifies what is exactly in the model (Franco et al., 2015). However, there is still a lack of understanding which complicates the use of BIM (Franco et al., 2015). Furthermore, cost estimation requires the use of another estimation software. Another necessity is the creation of a specific model for the contractor different than what is done by engineers or architects as estimation is more complex (Franco et al., 2015). BIM gives an indication of the costs and the schedule, however, this system does not directly compare the actual performance of the project with the planning (Haron Azam et al., 2018).

Many of the previous studies on project control tried to either find the cost or the time performance. Some researchers claim that there is still a lack of inclusion of both or that when there is, unreliable results are presented, for instance, Vanhoucke (2013), stated that the traditional, EVM method showed unreliable time forecast results at the end of the project, as regardless of the project performance it will finish on time. On another side, if studies tried to include both, cost and time, they generally focused on cost aspects of projects. Furthermore, for those which included both aspect, they did not all include project risks and project performance. Some did include indices affecting project performance but because various risks exist they did not cover them all. Moreover, according to Assaad et al. (2020), the models are based on a limited number of data from real construction practice. In the model developed by Assaad et al. (2020), different project risk that can affect the project performance on both aspect, cost and time were incorporated. In contrast to other studies, this study tried to have an integrated approach and included, negative and positive project performance. However, the study used data from industrial projects and did not add correlation between different project risks. The discussed studies did not present a comparison between planned and actual cost and time project performance while some did present easy forecasting methods others required more thorough knowledge to be used but also cost and time. In terms of forecasting, some research used a large set of historical data while others would use the most recent data set and use it to build a forecast. Hence, depending on the requirements, the available knowledge and the financial ability, some forecasts and project control methods could present better more or less advantages.

3.2 Criteria for a successful tool

As it is discussed in the Introduction (1.1), project success is the heart of project management and project control as a sub-function follows the same aim. The success factors are factors affecting the project success such as the external forces or the client attributes. We see that there is no unified definition for project success and that its definition tends to evolve. However, the framework of (Takim & Akintoye, 2002) gives a great idea of the relationship between the project performance, project success and success factors, it is shown in figure 2.

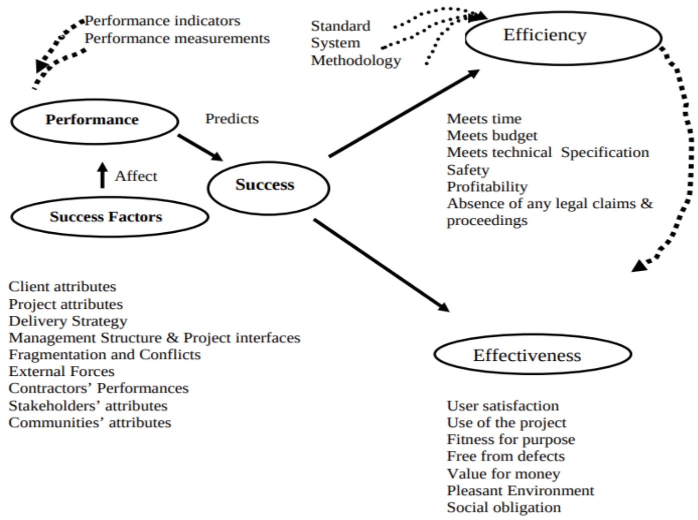


Figure 2: Relationship given by Takim and Akintoye (2002) between Success Factors, Project Performance & Project Success

A successful tool would be one which helps a project manager to have a successful project. Hence, it must firstly answer the project manager's requirements and needs. This also means that it should be easy to use and adaptable to different projects without being time consuming to adapt it. The tool must provide the project manager with the key performance indicators, which consist of the most important performance goals across all aspects of the project. Keeping track on those allows to identify where improvement can be done to optimize the project in terms of labour performance for instance.

In construction projects, it is important to know when there is deviation from the planned budget and why it occurred. Hence, understanding where the overrun happened allows to optimize and plan better future project or to adapt the current project by reducing waste and inefficiencies.
Whenever a cost variance happened, it is interesting to keep track on it to see where there is a better efficiency in terms of labour work or processes such as precast beams. On a further extent, it can help a project manager to see whether a certain process was worth it.
Moreover, in terms of time overrun, it is necessary to track any deviation as well. This is because it has an impact on the final project cost: if there is a time overrun, additional days of work are necessary. In addition, to reduce the client satisfaction, there would be a penalty due to the initial agreement with the client. Thus, understanding the reasons for more or less time than schedule would allow to decide either to provide training or consultation to improve the time allocation planning.
Another important aspect is to have milestones and track their completion during the construction of the project (Takim & Akintoye, 2002).

Company's scope and objectives might differ from a construction company to another and from a project to another. However, there are Key Performance Indicators (KPI), which can be useful to all. Those include for example productivity, performance of labour or employee satisfaction. Within the project management, KPI include for instance (Cruz Villazón et al., 2020):

- Project schedule
- Estimate of project completion
- Equipment cost per month
- Labor costs spent per month/per man-day
- Current resource allocation

Furthermore, from the literature review, it appeared that indices affecting project performance must be included to cover more aspects as this is not incorporated in all methods and it should cover both aspect, cost and time. Moreover, negative and positive project performance must be incorporated as well. By doing so, the method will present better the different uncertainties which characterize the construction sector.

4 Methodology

This section provides the steps which are followed to achieve the research goal and objectives with the support of the literature review discussed in the previous section. This research is called by Wieringa (2014), a TAR. This refers to research which uses of an experimental object to help a client and to learn about its effects and validate it in practice. Thus, the TAR methodology is used in this research to apply the project control tool in the MP project for GCC. By applying this method, three roles appear in this research: (1) technical researcher, (2) empirical researcher and (3) helper. For the first role, the project control tool design is done to solve the problem statement. For the second role, the research is realised to validate the design treatment. This is where the last role appears and where it makes this method different from others as it uses the MP project to help the client to monitor his construction project while validating the design in a client's engineering cycle. Hence, after this cycle, the knowledge question of the research is answered. If there is a need for improvement the iteration is done again to validate the tool (Wieringa, 2014). The figure 3 presents the three levels of the TAR methodology.

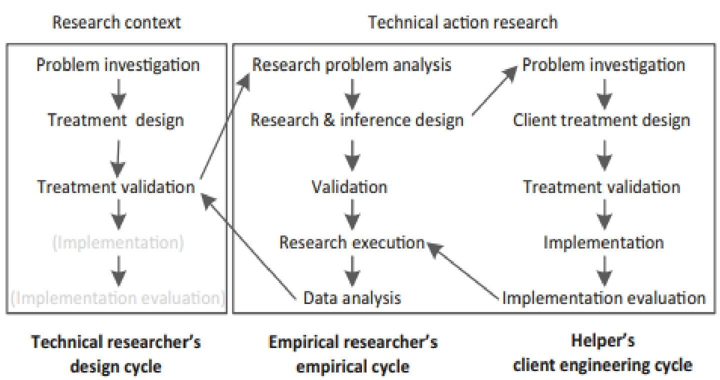


Figure 3: Three level structure of TAR (Wieringa, 2014)

The figure 4 provides an overview of how the research is structured with the steps followed which were inspired by the framework used by Assaad et al. (2020) and by the TAR methodology.

Figure 4: Research methodology flow chart

The research problem analysis and the literature review steps have already been done in the previous sections of the report. The problem of the host organisation has also been discussed, thus, the methodology will start with the presentation of the case study.

4.1 Investigate the case study

The case study is used as part of the methodology of Wieringa (2014), it does not only serve to validate the tool but also to draw out project managers' needs, requirements and the current issues faced in practice to do project control. This sub-section provides information on the involved parties in the MP project and on the study area.

Involved parties

The MP project is a joint venture between Transinvest Construction (TC) and GCC. Both companies are responsible of the execution and completion of the MP project. The collaboration is done to produce a quality project in shorter time by bringing resources together of labour, plant, equipment supervision logistic and experience. The responsibility of TC and GCC holds for the earthworks, roadworks, main walls, drainage, irrigation, telecommunication and electricity facilities.

The contract time for completion of work is calculated to be of 728 Days (24 months) but thanks to the joint venture it is reduced to 450 days (15 months), starting on the 16th of August 2021 and ending on the 26 th of November 2022. The required working hours of workers is of 8,5. The table 1 gives an overview of the involved parties of the MP project.

Table 1: Involved parties

Involved parties	Name
Client	Medine Ltd
Consulting Engineers	Servansingh Jadav and Partners
Architects	Architects studio
Environment consultant	Enviro Consult Ltd
Construction cost consultant	MLC
Contractor	Transinvest Construction Ltd
Contractor	General Construction co Ltd

Study area

It is a real estate development of 37 ha. It consists of four residential areas, with 470 plots, the master plan with the specific path categories, ponds, green spaces and swales is shown on figure 5. The project is currently at about 30-40% stage of development. It is divided into 5 zones: A, B, C, D and E. They are shown in figure 6, except for the zone E which corresponds to the road area from the roundabout in the South of the Master plan to the roundabout connected to the Magenta park.

GCC is responsible of the zone A, B and E1 (from the main road on the west to the roundabout in the south). The tasks' schedules and their related allowable and costs for zone A, B and E1 are being included to the analysis but the analysis excludes the other zones for which GCC is not responsible.

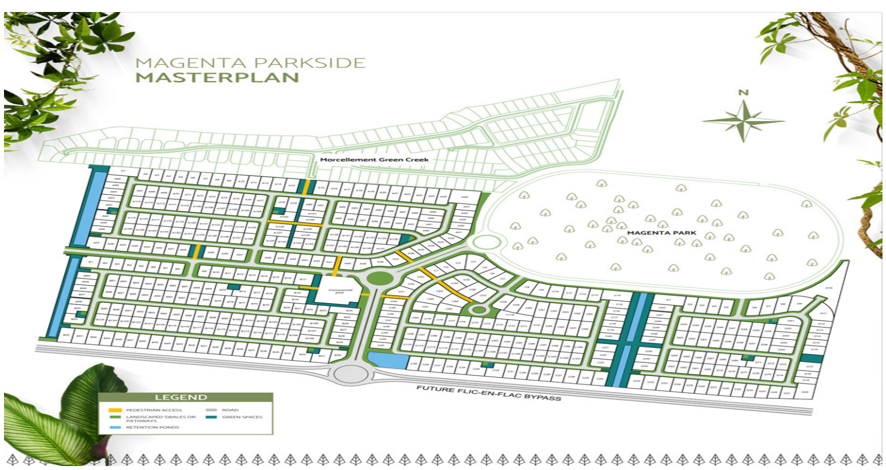


Figure 5: Master plan Magenta Parkside ("Magenta Parkside", n.d.)

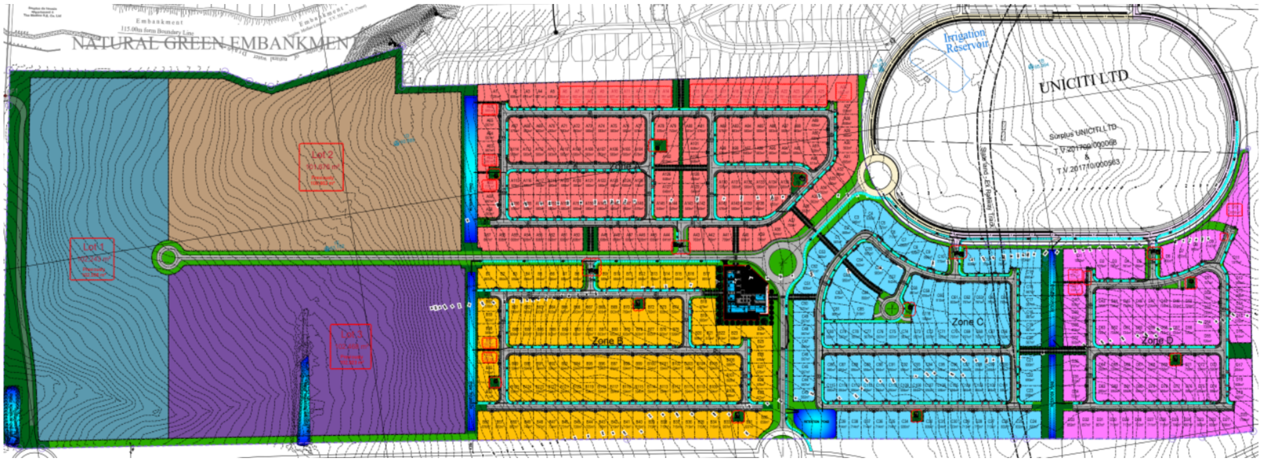


Figure 6: Master plan Magenta Parkside with zones

4.2 Define the design requirements

The requirements are classified by having functional and non-functional requirements. Most of the requirements of the tool are non-functional requirement and to make it measurable, the Project manager would act as an indicator of the performance of the requirement. These requirements are provided in a design brief.

In this step, interviewing is used to collect the required information for the research. Generally, research interviews have a structure and most of them are either semi-structured, structured or in-depth to provide comparable results. However, unstructured interviews are generally suggested in conducting long-term field work as they allow respondents to let them express in their own ways without influencing their answers (Jamshed, 2014). Hence, in this research, the decision to do an unstructured interview comes from the wish to provide answers without a priori parameters and make it be a free-flowing conversation without limiting boundaries of exploration. Thus, the interview seems like a conversation instead of an interview. The type of unstructured interview chosen is the non-directive one where, in-depth information is gathered but there is no pre-planned questions (Jamshed, 2014). This allows to make a fast brainstorming and come to new ideas while providing general information and learn from the experience of the respondent on projects and on the use of project control tool (Mueller & Segal, n.d.). The unstructured interview is held with the Project manager of GCC to define the required KPI for a construction project in Mauritius. It is also done with the quantity surveyor as in such projects, this person is the one providing the resources data so that the tool will have a similar setup to his expenses control, making it easier to incorporate the data to the newly developed tool. Moreover, it will provide another insight on the required performance indicators and measurements.

According to a research from Vasileiou et al. (2018), samples in qualitative research tend to be small to support the depth of case-oriented analysis which is the case in this research. Additionally, the respondents in this research provide the relevant information to the investigation, so that a larger sample size would not impact the outcomes of the research. However, to still add some reliability and reduce bias of the unstructured interviews, there is a combination with what has been discovered in the literature review to confirm elements which must be included in the tool or rejected. This will also provide another source of information to make sure that the elements added will support project managers effectively.

The result of this step is presented in the section 5 of the report.

4.3 Design the tool

In systems engineering, one of the step to design a system that answers the *"client's"* requirements is to determine the functionality of the system. It is being used in this research to describe what the tool must be able to do. It goes from the host organisation's demands (section 5) to specific design requirements. To do so, a Functional Analysis System Technique (FAST) diagram which stands for Functional Analysis System

Technique is created. It helps to give a concise and clear overview of the functions required for the tool. The steps to create it were taken from De Graaf (2019). One the main step is to first determine the tasks which represents in this research to the host organisation's needs for the tool. Another step is to find the functions which consists of using active verbs to describe an action or process required to achieve the tool's goal. Once this step is done, the functions are divided into basic and supporting functions. The first category represents functions that are essential to execute the host's organisation task. Without basic functions the other functions would be unnecessary while the other category of functions consists of increasing the host organisation's acceptance of the tool (De Graaf, 2019).

The functions that are found thanks to the interviews must be fulfilled by using *objects* to make sure that the demands of the project manager of the host organisation are correctly answered. Those objects which represent the requirements of the tool generally must be Specific, Measurable, Acceptable, Realistic, Time-related (SMART), however, the nature of the system, being a tool on Google Sheet, makes it complicated to give measurable objects. Thus, the objects consist of elements to be present to fulfill the required functions even though they are not measurable. Usually, combining the objects in different ways can result in different design alternatives (De Graaf, 2019). However, in this research, due to the time constraint, no design alternatives of the tool are proposed in this research. However, several iterations are still done throughout the design of the tool so that the design is improved progressively. Even though, no design alternative of the tool is provided in this research, propositions for further research are given in the *"Further research"* section.

The design requirement resulting from the requirement analysis are then included to the tool. The KPI will support the project manager in analysing the current and future trend of the project in terms of cost, revenues and schedule. Moreover, as project risk is also related to what was not already planned and its negative impact on the outcome of the project, the forecast of actual project cost and schedule will be done to help to control those risks by making them as predictable as possible. The tool will help to monitor the project risk related to cost and schedule but it will not provide the corrective actions required to reduce the risk or to avoid it.
Furthermore, the tool is designed in a way that will ensure an effective communication of the KPI results in due time all along the project construction.

The result of this step is presented in the section 6 of the report.

4.4 Validate the tool

As it was mentioned at the beginning of this chapter, in this methodology, the design is validated in a client's engineering cycle, so it is validated for the project manager of the host organisation to then, be validated for the purpose of answering the knowledge question.

The tool validation is necessary to find possible errors in the tool and to test its effectiveness for the required purpose. In other words, it is the verification that a tool implementation answers accurately the requirements of the project manager for the tool. The MP project is being used to demonstrate the tool's application in a real case and based on its results, a qualitative analysis is held. Unstructured interviews are done with the management team of the MP project. The respondents are the quantity surveyor and the project manager. This will allow to verify that the tool will be fast and easy to use but also to provide great and useful results (Thacker et al., 2004).

The representation of the conceptual tool must be compared to the real system, if it is an accurate representation from the perspective of the intended use of the tool, then it is a valid tool. Validation is done to quantify confidence in the predictive ability of the tool by comparison with experimental data. In this research, the validation could have been done with data from TC, on their part of the MP project (see section, 4.1) but due to a time constraint, the validation method is done by using data from the same project but on a date further in time not included yet to the tool so that the tool prediction can be validated (Thacker et al., 2004; Yin & McKay, 2018). This method is called the cross-validation. It is often to estimate the prediction errors of models. The exact type of cross-validation applied in this research is the single hold-out method (Berrar, 2018). Thus, there are two sets of data, the test set and what is referred as the training set by Berrar (2018). The test set is the part of the case data that will be used to validate the tool while the rest corresponds to the training set. The test set is generally done with 10 to 30 % of the available data while the other part of the data is used for comparison. In this research 20% of the data points will be used. This method will allow to validate the tool faster and to take the corrective actions more effectively. The error margin accepted is fixed by the project manager of the case study.

The section 7 provides details on the final validation results.

4.5 Collect data

The data is coming from the Quantity Surveyor of GCC and the project manager of the MP project who are providing the adjusted costs and quantities through meetings. The data related to originally schedule tasks is provided in the form of a Gantt chart from the Microsoft Project and the information concerning actual costs and time completion will be gathered thanks to the quantity surveyor input. The table 2 displays the input for zone A,B and E1 which is gathered for the research.

Table 2: Data input for zone A,B and E1

Originally schedule & current project state	
Tasks	Allowable, actual cost and revenue
Earthworks	Total
Drainage	Sub-contractor
Services	Labour
Irrigation Network	Material
Plot frontage	Transport
Roadworks	Plant & equipment
Miscellaneous work	Others

The validation of the data is included in the section 8 of the report.

4.6 Provide and analyse the results

Once, that the tool is validated for the research and for the host organisation requirement's, the results are presented and analysed in three sub-sections which are described below.

Provide a Guideline for using the tool in construction practice

This sub-section aims to give step by step guideline to use the developed tool to forecast cost and time performance properly. It answers the last sub-section of the main research question.

Give recommendation and have a discussion on case study results

This step mainly consists of answering the second main research question for the host company: (2) What will be the actual and forecasted performance indicators and the profit margin of the MP project for the overall project and for the labour and materials control resulting from the tool's result analysis?

Give a discussion on the tool

One of the step of the methodology of Wieringa (2014), *the implementation and evaluation*, occurs at the end of the design cycle, if the knowledge questions are answered and the client's needs as well, the next step can be taken. Otherwise, the iteration is done again to validate the tool. Hence, this step of Wieringa (2014) is done prior to the validation step. However, only the last iteration is being discussed. Moreover, this methodology step consists of discussing the results of the tool evaluation after the design implementation at the last iteration. In other terms, the challenges to apply the designed tool are mentioned and the recommendations to improve the tool and overcome the challenges are given.

The results of this step are provided in section 9.

5 Design requirements

The procedure followed in this section was discussed already in the *methodology section*, thus, only the organisation of the unstructured interviews and the results of the procedure are presented in this section.
However, prior to that, the meaning of some of the terms being used in this section and later in the research are described below to reduce confusion.
Progress refers to the revenue so the amount to be paid by the client (Medine Ltd) to the contractor (GCC). The *project progress* gives the percentage of progress obtained monthly or cumulatively.
The profit margin corresponds to the difference between all the company's expenses and its total progress (revenue).
The *allowable* represents the amount that GCC is allowed to expend based on the activities to be done, it excludes the profit margin. The *allowable release* corresponds to the actual allowable amount to be released based on the actual activities done during the project's construction phase.
The *costs* are the actual monthly expenditures of the company.
The term *variance* in this research and in project management is used to indicate a difference between what is budgeted or planned and what is actually accomplished.

To investigate and analyse requirements of the tool, the project manager's needs of the MP project are investigated to then be transformed into technical requirements through a functional analysis. Hence, eleven unstructured interviews with the project manager and two with the quantity surveyor were realized. The discussions with the project manager were done each week. The first one consisted of discussing the general design requirements of the tool, which tasks and data to include but also the main functions required from it. Following the discussion, those requirements would be transformed into functions and then into technical requirements. This means that the procedure was done step by step. In fact, once the requirements would be included to the tool, an evaluation would be done and if the project manager was not satisfied, a discussion on the improvement and alternatives was done. The design would then be improved until its implementation answers the project manager's needs so that the design element is validated and that process could be pursued. The evaluation would be done every week and once the design is validated, the discussion would generally follow with propositions on the next design element to be included and on possible new elements to be added to the tool. The section 6 gives additional details on the validation.
The two discussions with the quantity surveyor consisted of understanding the current expense control system of the company and also the plant and equipment control. The input and the data collection was discussed as well. The discussions leaded to a design that would follow a similar structure to the current expense control.

Using the unstructured interviews and following the system's engineering procedure of the requirement analysis, the main expectation, intended use of the system and measures of effectiveness are defined (De Graaf, 2019).
The host organisation expects the tool to be adaptable to change it easily from a construction project to another and also when the project performance are being updated during the construction phase.
The tool is to be used as a support to other existing tools for project control to the project manager to see key performance indicators related to cost and schedule effectively to then use them to reschedule or change the project's performance. The tool would be used monthly as the expenses control update is done monthly by the quantity surveyor of the project. This is also the case of different projects done by GCC.
To keep the project manager satisfied with the performance and the design of the tool, it must satisfy some characteristics. Those measures have to do with usability, reliability, ease of use and adaptability.
A design brief with the requirements of the tool can be found in table 3. In this table the requirements are displayed with their corresponding ID. Next to that, criteria are given, these show how the requirements are measured. The level at which the tool will meet this requirement is given in the performance column while, the bandwidth shows the minimum amount that the requirement needs to meet to be satisfied.

Table 3: Design brief

ID	*Description*	*Criterion*	*Performance*	*Bandwidth*
1.	**Project managers requirements**			
1.1	Connection between the schedule of tasks and expenditures	MUR & months	Fit all	Fit all
1.2	Connection between the schedule of tasks and the project's progress	MUR & months	Fit all	Fit all
1.3	Actual project cost and time performance indicators	MUR & months	-	Min. 2
1.4	Forecasts of project cost and performance	MUR & months	max.: 5% error	Fit
1.5	Forecasts of allowable release	MUR & months	max.: 5% error	Fit
2.	**Life cycle requirements**			
2.1	Adaptable to multiple construction projects	-	-	-
2.2	Fast display of results	Seconds	-	-
3.	**Usability requirements**			
3.1	Accessible to everyone	-	Yes or No	-
3.2	Simple to understand	-	Yes or No	-

6 Tool design

This section gives an overview of the final tool design.

Since the requirements are known, the functional analysis can be proceeded as well as the allocation of object. In order to provide a better overview on how functions are fulfilled by objects, the objects are connected to the function tree. The functional analysis is an iterative process, thus, the figure **??** displays the resulting diagram of the last iteration.The diagram can be read in two ways. It follows a *How ?* and *Why ?* logic which means that from left to right, it answers the *"How ?"* question: from general to specific functions and vice versa.

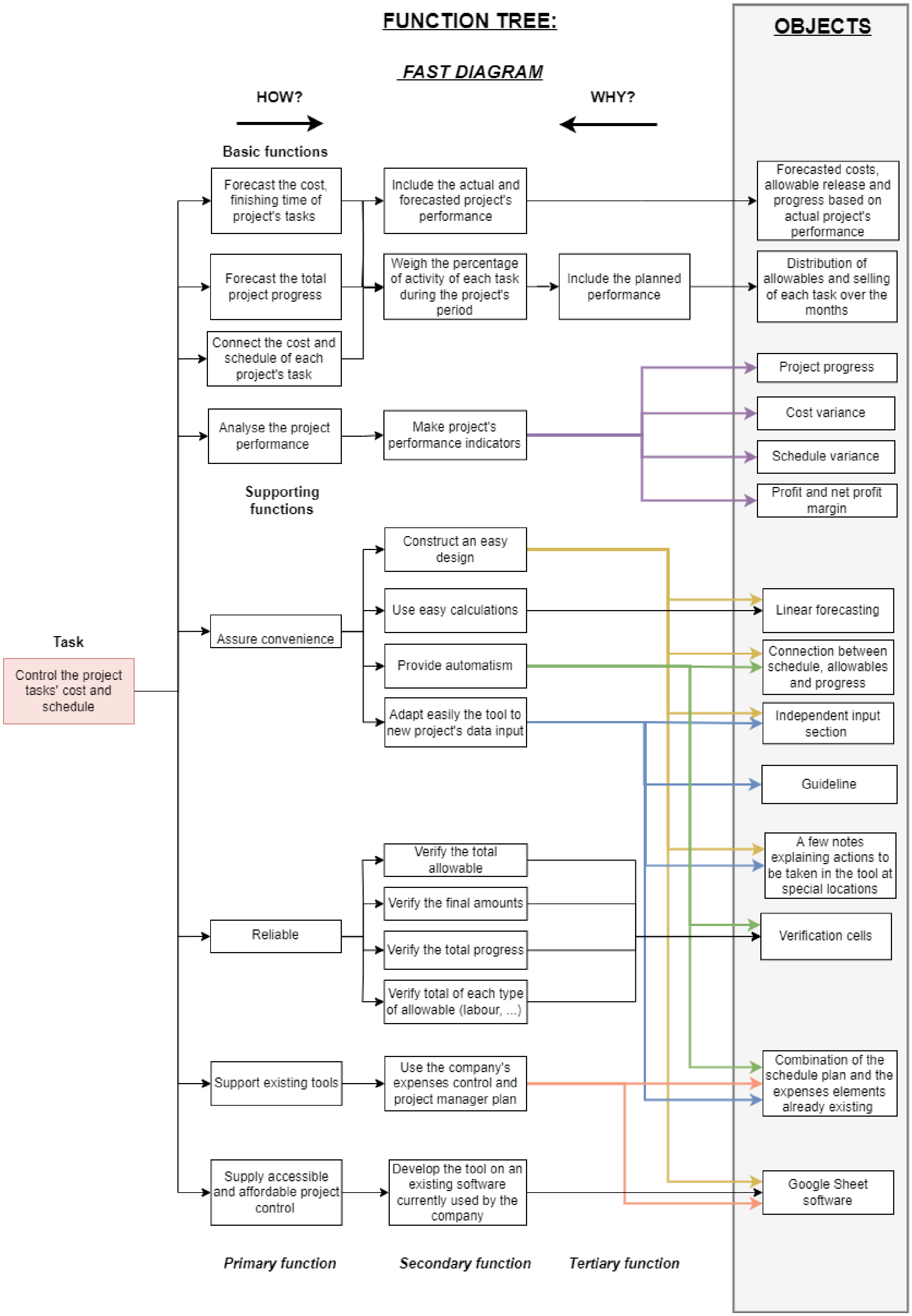


Figure 7: FAST diagram and object tree of the project control tool

The objects displayed previously resulted in the tool design which is being presented in this subsection.

One of the main function of the tool is to analyse the project performance. This analysis must consist of current project performance, occurring at the moment and also forecasted performance to support the project control and reduce unforeseen performances such as delay or costs overrun.
Thus, one of the requirements was to have KPI to give time and cost performances of the project. Thus, from the discussions with the project manager, the selected KPI are the following:

- Project progress
- Progress variance
- Cost variance
- Schedule variance
- Profit margin
- Net profit margin

Google Sheet was chosen to develop the tool because it is currently being used by the company to do the expense control of the project but also for the different control such as the plant control. Moreover, Google Sheet allows to collaborate easily and it does involve additional cost to the company. To obtain the previously mentioned indicators, the tool is divided in three sections. The first one consists of the planning distribution section while the second one includes the actual data and the forecasts components. The last section is made of multiple sheets which contain the results.
One of the main characteristic of the tool is its automatism. This is the main solution to be convenient to use for project managers and reduce time consumption for the project control analysis. The sections of the tool also considered this required function. This is why sheets were separated also into the ones requiring manual actions and the automated sheets. Thus, the two first sections involve manual input while the last one is automatically providing results. The appendix B gives an overview of the sheets as they are displayed on the tool.

Each section's design of the tool is being detailed, including figures taken from the tool.

Planning distribution section

One part of the tool is reserved for the planning of the project, planning in terms of schedule of tasks and their related allowable and progress amount in Mauritian rupees. How it looks like on the Google Sheet is shown in figure 8. The columns displayed in this figure must be filled manually. The second column called *header* could be omitted from the design if necessary but it allows the project manager to decide whether to include a task to the analysis or not if a *"H"* is inserted. As an example, in the analysis done in this research, all tasks type such as earthworks or drainage, are omitted in order to not repeat the values because their sub-tasks (e.g. *Site clearance*) values are already included. Moreover, it allows to have a clear design with headings. The category *"other"* permits to insert data which does not belong to any precise category of allowable.

Table of planned progress and allowables

Task Name	Header [2]	Zone	Progress (selling)	Total task allowable	Labour	Materials	Transport	Plant & equipment	Sub-contractors	Others	Start	Finish
INFRASTRUCTURE FOR MAGENTA PARKSIDE	H										3-8-21	16-12-22
On Site Works	H										16-8-21	16-12-22
GCC	H	**A-B-E1**									16-8-21	16-12-22
Zone A	H	**A**									25-8-21	15-11-22
Earthworks	H	**A**									9-9-21	15-11-22
Site clearance&top soil stripping to roads-reserves		**A**	1,651,305	1,501,187	179,278	1,020,407	301,502	0	0	0	9-9-21	16-9-21
Bulk earthworks to road and reserve (excavate,spread,compact fill)		**A**	313,892	285,357	25,266	0	260,091	0	0	0	11-11-21	8-12-21
Site clearance plots		**A**	368,714	335,194	44,456	0	60,459	230,279	0	0	18-8-22	25-10-22
Bulk earthworks to plots (cut,fill)		**A**	3,770,951	3,428,137	148,706	0	1,100,207	2,179,224	0	0	25-10-22	15-11-22
Final site clearance to plots upon completion		**A**	7,644,304	6,949,368	480,593	0	2,624,035	3,844,740	0	0	1-9-22	1-11-22
Drainage- culverts & ponds	**H**	**A**									8-12-21	8-8-22
Culverts Precasting		**A**	4,289,891	3,899,901	254,274	2,323,883	179,074	178,090	0	964,580	8-12-21	14-6-22
Culverts installation (plot entrance and road crossings)		**A**	5,034,668	4,576,971	140,231	4,436,740	0	0	0	0	5-5-22	26-7-22
Retention pond		**A**	5,800,294	5,272,994	394,941	1,552,881	877,644	2,447,528	0	0	19-1-22	8-8-22
Services (excavation, bedding,[...], testing)	**H**	**A**									22-12-21	24-8-22
ELECTRICAL WORKS TOTAL		**A**	9,343,586	8,494,169	2,048,257	4,431,930	821,059	542,233	0	650,691	22-12-21	26-7-22
WATER RETICULATION NETWORK		**A**	5,246,220	4,769,291	1,000,433	2,523,670	448,573	590,291	180,000	26,322	22-12-21	24-8-22
TELECOM WORKS		**A**	3,831,831	3,483,483	779,494	1,318,601	280,344	528,696	516,564	59,784	8-2-22	26-7-22
SERVICES ROAD CROSSINGS AND PLOT CONNECTIONS [5]		**A**	1,936,849	1,760,771	325,354	919,356	172,220	184,580	77,396	81,866	14-4-22	12-7-22

Figure 8: Project planning: tasks, planned progress, allowable and schedule

The previous elements are necessary as they will allow to distribute all the values for each tasks over the months of the project. In fact, once those columns are filled with data, the duration of the tasks, the month of start and end as well as the related years are filled automatically by the tool. Moreover, for each task the weighted percentage of task that must be completed each month of their duration is also given automatically. This percentage is simply given by the following formula:

Weighted percentage= $1/Task's\ duration$

The figure 9 shows the previously discussed components. Those columns are normally hidden to increase visibility and clarity in the tool without unnecessary elements displayed.

Table of planned progress and allowables

Task Name	Duration (Month)	Month start	Year start	Month end	Year end	Weighted %
Site clearance plots	2	8	2022	10	2022	50.00%
Bulk earthworks to plots (cut,fill)	1	10	2022	11	2022	100.00%
Final site clearance to plots upon completion	2	9	2022	11	2022	50.00%
Drainage- culverts & ponds	8	12	2021	8	2022	
Culverts Precasting	6	12	2021	6	2022	16.67%
Culverts installation (plot entrance and road crossings)	2	5	2022	7	2022	50.00%
Retention pond	7	1	2022	8	2022	14.29%
Services (excavation, bedding,[...], testing)	8	12	2021	8	2022	
ELECTRICAL WORKS TOTAL	7	12	2021	7	2022	14.29%
WATER RETICULATION NETWORK	8	12	2021	8	2022	12.50%
TELECOM WORKS	5	2	2022	7	2022	20.00%
SERVICES ROAD CROSSINGS AND PLOT CONNECTION	3	4	2022	7	2022	33.33%

Figure 9: Months duration and weighted percentage

The next part of the design aims to display for every month, the percentage of tasks (see figure 10) which will then allow to obtain the associated summation of monthly distributed amount. The later is presented in the tool in four tables as shown in figure 11. The first is composed of the monthly distributed activity in Mauritian rupees (MUR). The second gives the monthly percentage of planned progress. The third and fourth ones represent the cumulative distributed activity amount, respectively in MUR and in percentage.

The figures do not show all the available cells of the tool but there are additional cells which allow to keep the automatism. Those cells are hidden manually but they can be easily displayed again and if necessary extended so that the automatism of the tool is kept. Those extensible cells are present for the distribution table components, and in the table of planned progress and allowable. To remove any possible confusion, when no data is included, empty cells are shown instead of error messages.

Some cells are being used to do an instantaneous verification. This is the case for the weighted percentage, to verify that the total percentage of task done displayed in the distribution table is equal to 100 % , if it is not the case, the percentage is displayed in red (refer to figure 10). Moreover, to verify that the total amounts planned for the project progress and the different allowable (e.g. labour, materials,...) corresponds to the amounts obtained with the distribution table, additional verification cells are present (refer to figure 11). In case that there is an unexpected error, the planned total value is displayed in red, otherwise, the cells stay empty as it can be seen in the figure 11.

Table of planned progress and allowables

Task Name	Weighted %	Verif.total.line	Month-Year	8-2021	9-2021	10-2021	11-2021	12-2021	1-2022	2-2022	3-2022	4-2022	5-2022	6-2022	7-2022
Earthworks															
Site clearance&top soil stripping to roads-reserves	100.00%	100.00%			100.00%										
Bulk earthworks to road and reserve (excavate,spread,compact fill)	100.00%	100.00%					100.00%								
Site clearance plots	50.00%	100.00%													
Bulk earthworks to plots (cut,fill)	100.00%	100.00%													
Final site clearance to plots upon completion	50.00%	100.00%													
Drainage- culverts & ponds															
Culverts Precasting	16.67%	100.00%						16.67%	16.67%	16.67%	16.67%	16.67%	16.67%		
Culverts installation (plot entrance and road crossings)	50.00%	100.00%											50.00%	50.00%	
Retention pond	14.29%	100.00%							14.29%	14.29%	14.29%	14.29%	14.29%	14.29%	14.29%
Services (excavation, bedding,[...], testing)															
ELECTRICAL WORKS TOTAL	14.29%	100.00%						14.29%	14.29%	14.29%	14.29%	14.29%	14.29%	14.29%	
WATER RETICULATION NETWORK	12.50%	100.00%						12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%	12.50%
TELECOM WORKS	20.00%	100.00%								20.00%	20.00%	20.00%	20.00%	20.00%	
SERVICES ROAD CROSSINGS AND PLOT CONNECTION	33.33%	100.00%										33.33%	33.33%	33.33%	

Figure 10: Planning distribution table and verification

Amount RS

Monthly distributed activity in MUR																		Total	VERIFICATION
Planned progress	6,350,417	18,926,939	7,944,790	6,664,309	0,762,53	13,831,396	4,597,76	20,555,943	22,141,731	29,230,939	31,149,320	27,573,823	28,358,792	40,459,418	25,341,273	22,418,992	1,744,564	328,052,948	
Planned total allo	3,540,321	11,231,725	4,989,750	3,825,677	7,551,33	10,341,211	11,037,90	16,454,435	17,896,061	24,340,795	26,084,778	22,834,326	23,547,934	34,548,503	20,804,735	20,380,902	1,585,968	260,996,367	
Labour allowable	636,009	947,816	815,232	661,275	1,190,98	1,614,478	1,770,377	3,539,811	3,897,280	4,424,735	5,042,901	5,070,945	5,000,466	5,335,848	2,303,910	996,551		43,248,624	
Materials allowab	65,229	1,840,593	1,028,769	65,229	2,158,92	3,217,066	3,480,786	6,316,321	6,978,891	12,073,789	12,537,828	8,095,412	8,192,896	12,242,442	1,635,689	6,910,032		86,839,896	
Transport allowab	452,267	975,571	758,935	712,358	1,108,84	1,441,842	1,497,910	1,567,190	1,698,337	1,860,948	2,187,676	2,175,278	2,080,712	4,489,618	4,697,735	1,159,595		28,864,819	
Plant &equipment	233,789	233,789	233,789	233,789	450,067	1,345,319	1,451,058	1,789,686	2,002,255	2,059,548	2,455,855	2,493,911	2,546,107	5,634,442	7,933,049	5,829,851		36,926,301	
Sub-contractors a		150,000			22,500	22,500	125,813	399,041	426,990	998,025	1,149,191	2,450,762	2,347,266	1,467,937	945,972	1,292,349	1,585,968	13,384,314	
Others allowable	2,153,026	7,083,956	2,153,026	2,153,026	2,620,01	2,700,006	2,711,963	2,842,386	2,892,309	2,923,749	2,711,327	2,548,017	3,380,487	5,378,216	3,288,379	4,192,525		51,732,414	

Monthly distributed activity in %																		Total
Planned progress	1.94%	5.77%	2.42%	2.03%	3.28%	4.22%	4.45%	6.27%	6.75%	8.91%	9.50%	8.41%	8.64%	12.33%	7.72%	6.83%	0.53%	100%

Cumulative RS

Cumulative distributed activity in MUR																	
Planned progress	6,350,417	25,277,356	33,222,146	39,886,455	0,648,99	64,480,389	9,078,15	99,634,095	21,775,82	151,006,765	82,156,08	209,729,908	238,088,700	278,548,118	303,889,391	326,308,383	328,052,948
Planned total allo	3,540,321	14,772,045	19,761,796	23,587,473	1,138,81	41,480,023	2,517,93	68,972,365	86,868,426	111,209,221	37,293,99	160,128,325	183,676,259	218,224,762	239,029,498	259,410,400	260,996,367
Labour allowable	636,009	1,583,825	2,399,057	3,060,332	4,251,32	5,865,799	7,636,176	11,175,987	15,073,266	19,498,001	24,540,903	29,611,848	34,612,314	39,948,162	42,252,073	43,248,624	
Materials allowab	65,229	1,905,822	2,934,591	2,999,820	5,158,74	8,375,809	11,856,59	18,172,916	25,151,807	37,225,596	49,763,425	57,858,837	66,051,733	78,294,175	79,929,864	86,839,896	
Transport allowab	452,267	1,427,838	2,186,773	2,899,132	4,007,97	5,449,819	6,947,730	8,514,920	10,213,257	12,074,205	14,261,881	16,437,159	18,517,872	23,007,489	27,705,224	28,864,819	
Plant & equipmen	233,789	467,577	701,366	935,155	1,385,22	2,730,540	4,181,598	5,971,284	7,973,539	10,033,087	12,488,942	14,982,853	17,528,960	23,163,402	31,096,451	36,926,301	
Sub-contractors	0	150,000	150,000	150,000	172,500	195,000	320,813	719,854	1,146,843	2,144,868	3,294,059	5,744,821	8,092,087	9,560,024	10,505,997	11,798,346	13,384,314
Others allowable	2,153,026	9,236,983	11,390,009	13,543,035	6,163,04	18,863,058	21,575,01	24,417,405	27,309,713	30,233,463	32,944,790	35,492,806	38,873,294	44,251,510	47,539,889	51,732,414	

Cumulative %

Cumulative distributed activity in %																	
Planned progress	1.94%	7.71%	10.13%	12.16%	15.44%	19.66%	24.11%	30.37%	37.12%	46.03%	55.53%	63.93%	72.58%	84.91%	92.63%	99.47%	100.00%
Total allowable %	1.36%	5.66%	7.57%	9.04%	11.93%	15.89%	20.12%	26.43%	33.28%	42.61%	52.60%	61.35%	70.38%	83.61%	91.58%	99.39%	100.00%
Labour allowable	1.47%	3.66%	5.55%	7.08%	9.83%	13.56%	17.66%	25.84%	34.85%	45.08%	56.74%	68.47%	80.03%	92.37%	97.70%	100.00%	
Materials allowab	0.08%	2.19%	3.38%	3.45%	5.94%	9.65%	13.65%	20.93%	28.96%	42.87%	57.30%	66.63%	76.06%	90.16%	92.04%	100.00%	
Transport allowab	1.57%	4.95%	7.58%	10.04%	13.89%	18.88%	24.07%	29.50%	35.38%	41.83%	49.41%	56.95%	64.15%	79.71%	95.98%	100.00%	
Plant & equipmen	0.63%	1.27%	1.90%	2.53%	3.75%	7.39%	11.32%	16.17%	21.59%	27.17%	33.82%	40.58%	47.47%	62.73%	84.21%	100.00%	
Sub-contractors %	0.00%	1.12%	1.12%	1.12%	1.29%	1.46%	2.40%	5.38%	8.57%	16.03%	24.61%	42.92%	60.46%	71.43%	78.49%	88.15%	100.00%
Others allowable	4.16%	17.86%	22.02%	26.18%	31.24%	36.46%	41.71%	47.20%	52.79%	58.44%	63.68%	68.61%	75.14%	85.54%	91.90%	100.00%	

Figure 11: Distributions and total amount verification

Actual data and forecasts section

The second section of the tool presented in the second sheet serves as input page. In fact, this sheet was created to update easily the project every month by adding the new data. The monthly allowable release and cost of the project are added while the tool gives the cumulative data automatically. As it can be observed on the figure 12, the actual update date is also added to the tool. This is important as changing the date of the update at this location will change it automatically everywhere on the tool as it is connected to other functions. Thus, it will give as results to the project manager the updated results only. However, if necessary a different date than the update date can be inserted to obtain data from a different month. Note that every sheet, also has an update date section to change it conveniently only for one sheet.

Actual update: May-2022

Monthly & cumulative actual project data

	Planned	Section	Item	Type	Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022	Jun-2022	Jul-2022
Total progress planned	328,052,948	Monthly	Progress		0	12,068,861	8,234,540	16,572,371	16,398,610	14,693,230	15,037,551	18,338,886	17,313,841	28,970,784		
		Monthly	Progress %		0%	4%	3%	5%	5%	4%	5%	6%	5%	9%		
Total allowable release planned	43,248,624	Monthly	Labour	Release	0	704,007	649,825	808,819	1,105,818	847,642	1,169,617	1,066,400	1,690,777	2,469,317		
		Monthly	Labour	Cost	91,378	208,869	342,547	375,788	889,452	960,579	2,081,030	2,449,330	3,661,012	3,566,669		
	86,839,896	Monthly	Materials	Release	0	65,229	65,229	984,508	4,311,426	3,297,756	5,802,448	1,978,582	1,994,836	9,400,119		
		Monthly	Materials	Cost	225,122	361,940	184,080	859,065	6,275,939	3,629,097	6,044,793	5,137,405	8,225,535	5,621,949		
	28,864,819	Monthly	Transport	Release	0	565,374	463,460	1,312,488	1,448,854	2,221,070	240,781	662,213	1,781,912	2,431,947		
		Monthly	Transport	Cost	96,932	119,943	161,381	730,493	1,294,340	1,469,271	2,272,356	1,770,771	1,860,612	2,599,852		
	36,926,301	Monthly	Plant & equipment	Release	0	1,057,441	400,537	2,373,305	1,199,801	2,203,870	1,401,871	764,568	1,325,096	2,434,650		
		Monthly	Plant & equipment	Cost	50,823	349,644	527,208	1,112,687	2,899,463	2,990,696	4,866,629	3,435,984	5,773,338	6,339,420		
	13,384,314	Monthly	Sub-contractor	Release	150,000	0	0	0	0	0	3,659,311	4,452,274	3,956,164	0		
		Monthly	Sub-contractor	Cost	47,360	11,800	0	27,426	331,200	343,195	3,746,536	5,701,170	2,168,388	865,839		
	51,732,414	Monthly	Others	Release	0	0	0	0	55,758	214,636	183,765	803,349	1,326,065	1,543,910		
		Monthly	Others	Cost	0	0	0	0	0	0	0	0	0	0		
	260,996,367	Monthly	Total	Release	5,092,230	4,545,079	3,732,077	7,632,146	6,416,815	10,988,827	14,593,502	11,837,962	14,313,774	20,653,663		
		Monthly	Total	Cost	1,321,833	3,191,112	2,238,033	5,083,878	13,177,712	10,877,977	20,543,049	20,072,856	23,403,951	20,682,459		
Total progress planned	328,052,948	Cumulative	Progress		0.00	12,068,860.55	20,303,400.32	36,875,770.84	53,274,381.03	67,967,610.89	83,005,162.20	101,344,047.99	118,657,889.39	147,628,673.41		
		Cumulative	Progress %		0%	4%	6%	11%	16%	21%	25%	31%	36%	45%		
Total allowable release planned	43,248,624	Cumulative	Labour	Release	0	704,007	1,353,832	2,162,652	3,268,469	4,116,112	5,285,728	6,352,128	8,042,905	10,512,221		
		Cumulative	Labour	Cost	91,378	300,247	642,795	1,018,583	1,908,035	2,868,614	4,949,644	7,398,973	11,059,986	14,626,655		
	86,839,896	Cumulative	Materials	Release	0	65,229	130,458	1,114,966	5,426,392	8,724,149	14,526,597	16,505,179	18,500,015	27,900,134		
		Cumulative	Materials	Cost	225,122	587,062	771,142	1,630,207	7,906,146	11,535,243	17,580,036	22,717,442	30,942,976	36,564,926		
	28,864,819	Cumulative	Transport	Release	0	565,374	1,028,834	2,341,322	3,790,175	6,011,245	6,252,026	6,914,239	8,696,151	11,128,098		
		Cumulative	Transport	Cost	96,932	216,875	378,256	1,108,749	2,403,090	3,872,361	6,144,716	7,915,488	9,776,099	12,375,951		
	36,926,301	Cumulative	Plant & equipment	Release	0	1,057,441	1,457,978	3,831,284	5,031,085	7,234,954	8,636,825	9,401,393	10,726,489	13,161,139		
		Cumulative	Plant & equipment	Cost	50,823	400,468	927,676	2,040,363	4,939,826	7,930,522	12,797,150	16,233,134	22,006,472	28,345,891		
	13,384,314	Cumulative	Sub-contractor	Release	150,000	150,000	150,000	150,000	150,000	150,000	3,809,311	8,261,585	12,217,749	12,217,749		
		Cumulative	Sub-contractor	Cost	47,360	59,160	59,160	86,586	417,786	760,981	4,507,517	10,208,687	12,377,075	13,242,914		
	51,732,414	Cumulative	Others	Release	0	0	0	0	55,758	270,393	454,159	1,257,508	2,583,573	4,127,484		
		Cumulative	Others	Cost	0	0	0	0	0	0	0	0	0	0		
	260,996,367	Cumulative	Total	Release	5,092,230	9,637,308	13,369,385	21,001,531	27,418,347	38,407,174	53,000,676	64,838,638	79,152,412	99,806,076		
		Cumulative	Total	Cost	1,321,833	4,512,945	6,750,978	11,834,856	25,012,568	35,890,545	56,433,594	76,506,450	99,910,401	120,592,860		

Figure 12: Actual data: allowable release, cost, progress

The second section of the tool, also includes the forecasts' intersect and slope as a part of the forecast procedure has to be done manually.
The forecasts are done for the expenses, the allowable release and the progress, as it can be seen in the figure 13.
The reason for choosing a linear forecast comes from the wish to construct an easy design with easy calculations which can be understood easily by anyone, thus, it can be adapted depending on the managers requirements and the project's objectives. Moreover, the coefficient of determination also called R-squared was found prior to this decision. This measure is used in regression models to see variance between two variables. In this case, the cost, allowable release, progress were compared with the progress percentage. Several trends based on the actual data were compared and the linear regression gave better R-squared results than the other trends. The values were higher than 0.78 which indicates a great linear relationship of the values.

Similar to some previous research, the forecasts use recent observations and small set of data. Hence, forecasts are done based on the cumulative performance obtained at the last month instead of following the trend from the beginning of the project. The reason for using only this cumulative data is that it gives an idea to the project management of what to expect if the current trend is followed in terms of project progress, allowable release and cost.
For the total project estimations, the trend is using the progress percentage of the project as x-values while for the separated allowable such as labour, the progress is based on the allowable planned and the actual allowable release. It is not done in the same way for both as the project project is only available for the overall project tasks but it is not separated by allowable, in the current expenses' control of this project.
Note that on the figure 13, the other category does not have its intersects and slope calculated, this is because it has been excluded of this analysis due to missing updated actual data in this category.

Cumulative forecast project data

Progress based on allowable	Labour	0%	2%	3%	5%	8%	10%	12%	15%	19%	24%		
	Materials	0%	0%	0%	1%	6%	10%	17%	19%	21%	32%		
	Transport	0%	2%	4%	8%	13%	21%	22%	24%	30%	39%		
	Plant & equipmen	0%	3%	4%	10%	14%	20%	23%	25%	29%	36%		
	Sub-contractor	1%	1%	1%	1%	1%	1%	28%	62%	91%	91%		
	Others	0%	0%	0%	0%	0%	1%	1%	2%	5%	8%		

Labour	Forecast allowable	m	43,248,624
		b	0
	Forecast cost	m	62,468,110
		b	-557,148

Transport	Forecast allowable	m	28,864,819
		b	0
	Forecast cost	m	30,857,688
		b	479,553

Sub-contractor	Forecast allowable	m	13,384,314
		b	0
	Forecast cost	m	2,929,267
		b	10,568,959

Materials	Forecast allowable	m	86,839,896
		b	0
	Forecast cost	m	51,936,524
		b	19,878,633

Plant & equipment	Forecast allowable	m	36,926,301
		b	0
	Forecast cost	m	96,149,886
		b	-5,923,504

Others	Forecast allowable	m	
		b	
	Forecast cost	m	
		b	

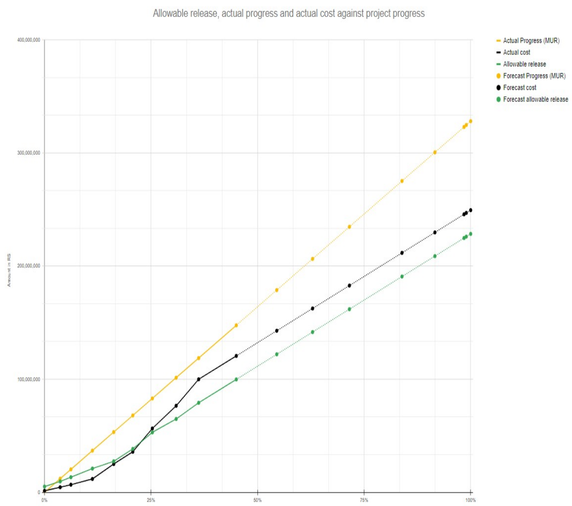
Total cumulative	Forecast progress	m	328,052,948
		b	0
	Forecast cost	m	234,199,447
		b	15,199,649
	Forecast allowable	m	233,873,377
		b	-5,440,399

Figure 13: Forecasts' intersect and slope

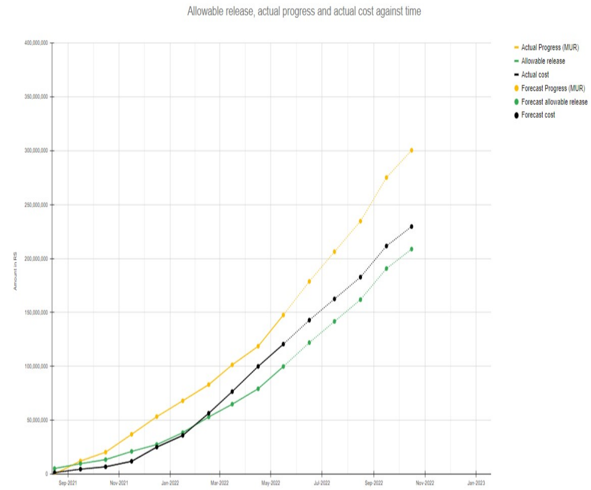
Results' design section

The result's section of the tool has several sheets. Those results include the present performance of the project and the forecasts.
One of the sheet (*"Total sheet"*) contains the results concerning the total of all the amount. Thus, the total monthly allowable release, planned allowable, planned and actual progress and cost are displayed in this sheet. The forecasts are included automatically as soon as the trend of actual data stops.
To communicate and share effectively the results of the tool, histograms are used in addition to tables. Moroever, the planned and current data of the MP are gathered to build S-curves to show the cumulative progress of the MP project with reference to time and the growth of cost. The S Curve is being used because it is easy to adapt and can display real-time cumulative data from the different project tasks and allows to compare them with the projected data effectively.

Three graphs are displayed in the sheet. The first one which is shown in figure 15, compares the planned project progress with the actual progress over the months with the project cost and their forecast. The second one, in figure 14a, compares the actual data of the project, the allowable release, the cost and progress against the percentage of actual progress while the last figure, figure 14b, compares them against time. It is first compared to the percentage of progress to give a fast idea of what would be the values at a certain progress of the project so for instance if at 80 % of project completion the margin between the allowable release and the progress is as planned or not. On the other hand, the comparison against time give a direct idea of the project performance every month to easily see if one month had an unexpected great or negative result which could then be analysed to improve the future works.



(a) Allowable release, actual cost and progress over percentage progress



(b) Allowable release, actual cost and progress over time

Figure 14: Resulting curves of total amount

Total

Actual update	May-2022
Difference planned vs actual progress (cumulative) [1]	-1%
Planned finish date [2]	Dec-2022
Actual finish date [3]	Dec-2022
Time delay in months	0

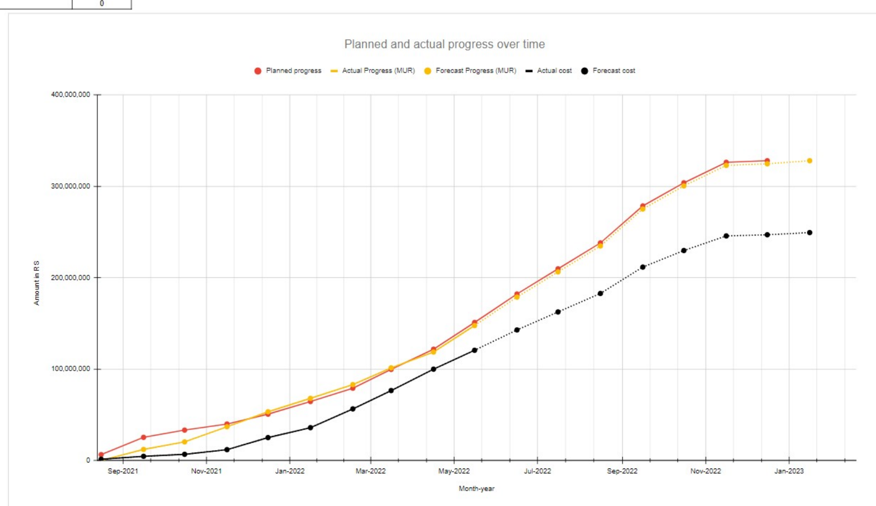


Figure 15: Planned and actual progress with expenses over time

The histograms display the monthly results as well as the cumulative results until the chosen date such as the update day of the data input which can be inserted at the top of the sheet or in the *"actual data"* section of the tool. Moreover, the KPI are being displayed in those histograms in addition to the tables.

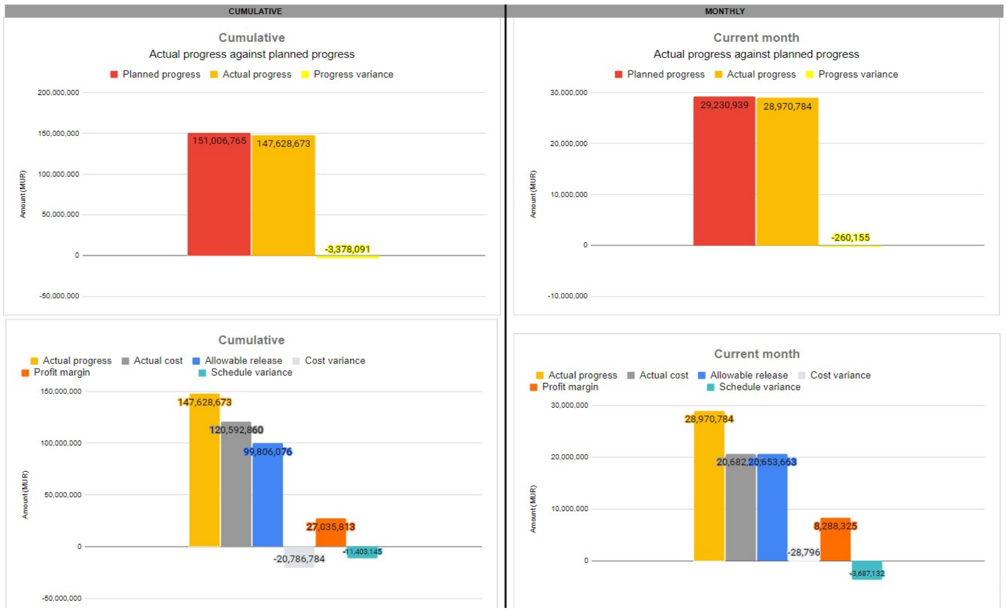


Figure 16: Cumulative and monthly performance of overall project

The figure 16 shows the table as displayed in the tool with the cumulative data for every month until the update date and then from the update date, a forecast is automatically done based on the calculations that were done in the previous section of the tool. The figure 18, presents the table which only shows the user the current performance of the project based on the last project update. This is done to reduce an excessive amount of data and provide directly the last update. The tables presenting the monthly results are shown in the appendix A.

Cumulative																		
Month-Year	Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022	Jun-2022	Jul-2022	Aug-2022	Sep-2022	Oct-2022	Nov-2022	Dec-2022	Jan-2023
Planned progress %	2%	8%	10%	12%	15%	20%	24%	30%	37%	46%	56%	64%	73%	85%	93%	99%	100.00%	
Actual Progress %	0%	4%	6%	11%	16%	21%	25%	31%	36%	45%	54%	63%	72%	84%	92%	98%	99%	100%
Planned progress	6,350,417	25,277,356	33,222,146	39,886,455	50,648,992	64,480,389	79,078,151	99,634,095	121,775,826	151,006,765	182,156,085	209,729,908	238,088,700	278,548,118	303,889,391	326,308,383	328,052,948	
Actual Progress (MUR)	0	12,068,861	20,303,400	36,875,771	53,274,381	67,967,611	83,005,162	101,344,048	118,657,889	147,628,673								
Planned total allowable	3,540,321	14,772,045	19,761,796	23,587,473	31,138,812	41,480,023	52,517,930	68,972,365	86,868,426	111,209,221	137,293,999	160,128,325	183,676,259	218,224,762	239,029,498	259,410,400	260,996,367	
Allowable release	5,092,230	9,637,308	13,369,385	21,001,531	27,418,347	38,407,174	53,000,676	64,838,638	79,152,412	99,806,076								
Actual cost	1,321,833	4,512,945	6,750,978	11,834,856	25,012,568	35,890,545	56,433,594	76,506,450	99,910,401	120,592,860								
Forecast Progress (MUR)	0	12,068,861	20,303,400	36,875,771	53,274,381	67,967,611	83,005,162	101,344,048	118,657,889	147,628,673	178,777,994	206,351,817	234,710,609	275,170,027	300,511,300	322,930,292	324,674,856	328,052,948
Forecast cost	1,321,833	4,512,945	6,750,978	11,834,856	25,012,568	35,890,545	56,433,594	76,506,450	99,910,401	120,592,860	142,830,592	162,515,750	182,761,303	211,645,584	229,736,908	245,741,993	246,987,451	249,399,096
Forecast allowable release	5,092,230	9,637,308	13,369,385	21,001,531	27,418,347	38,407,174	53,000,676	64,838,638	79,152,412	99,806,076	122,012,847	141,670,598	161,887,964	190,732,029	208,798,165	224,780,967	226,024,691	228,432,978
Progress delay/ahead	Progress delay	Progress delay	Progress delay	Progress delay	Progress ahead	Progress ahead	Progress ahead	Progress ahead	Progress delay	Progress delay								
Progress variance	-6,350,417	-13,208,495	-12,918,745	-3,010,684	2,625,389	3,487,222	3,927,011	1,709,953	-3,117,936	-3,378,091								
Cost overrun/underrun	Cost underrun	Cost underrun	Cost underrun	Cost underrun	Cost underrun	Cost underrun	Cost overrun	Cost overrun	Cost overrun	Cost overrun								
Cost variance (allowable release-cost)	3,770,397	5,124,363	6,618,407	9,166,675	2,405,778	2,516,629	-3,432,918	-11,667,812	-20,757,989	-20,786,784								
Profit / No profit	No profit	Profit	Profit	Profit	Profit	Profit	Profit	Profit	Profit	Profit								
Profit margin (actual progress-cost)	-1,321,833	7,555,915	13,552,422	25,040,914	28,261,813	32,077,066	26,571,568	24,837,598	18,747,488	27,035,813								
Net profit margin (Actual progress-actual cost)/Actual progress	#DIV/0!	63%	67%	68%	53%	47%	32%	25%	16%	18%								
Ahead/behind scheduled allowable release	Schedule ahead	Schedule delay	Schedule delay	Schedule delay	Schedule delay	Schedule delay	Schedule ahead	Schedule delay	Schedule delay	Schedule delay								
Schedule variance (allowable release-planned allowable)	1,551,909	-5,134,737	-6,392,411	-2,585,942	-3,720,465	-3,072,849	482,746	-4,133,727	-7,716,014	-11,403,145								

Progress at completion	328,052,948
Cost at completion	249,399,096
Allowable release at completion	228,432,978

Figure 17: Cumulative data of overall project

Cumulative last update												
Month-Year										May-2022		
Progress delay/ahead										Progress delay		
Progress variance										-3,378,091		
Cost overrun/underrun										Cost overrun		
Cost variance *(allowable release-cost)*										-20,786,784		
Profit / No profit										Profit		
Profit margin *(actual progress-cost)*										27,035,813		
Net profit margin *(Actual progress-actual cost)/Actual progress*										18%		
Ahead/behind scheduled allowable release										Schedule delay		
Schedule variance *(allowable release-planned allowable)*										-11,403,145		
Planned progress %										46%		
Actual Progress %										45%		
Planned allowable										111,209,221		
Allowable release										99,806,076		
Planned progress										151,006,765		
Actual progress (MUR)										147,628,673		
Actual cost										120,592,860		

Figure 18: Last update of cumulative data of overall project

The other part of the result's section which consists of the last sheets of the tool, is similar but divided in allowable: labour, materials, transport, plant and equipment, sub-contractors and "others". This allows to have a better view on the different performance. The labour category has a slightly different design as it also displays an estimation of workers required based on the allowable planned. However, except this small difference it has the same design for all of the other allowable, thus, the figure 19 and 20 give an idea of this design while the figure 21 shows the only distinguishable element.

Even though the research objective was mainly to obtain indicators on the overall project output, the labour and materials, the data for the other categories such as transport are included as well to the tool as they might be useful to understand the targeted elements and be used to further improve the tool by adding new functions.

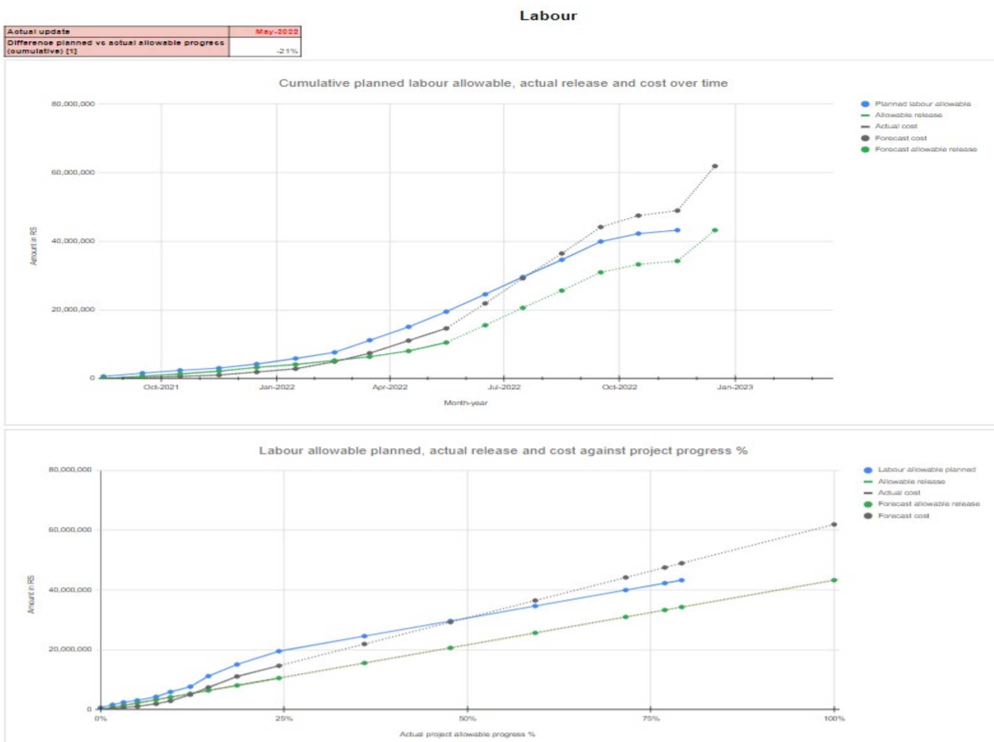


Figure 19: Labour S-curves

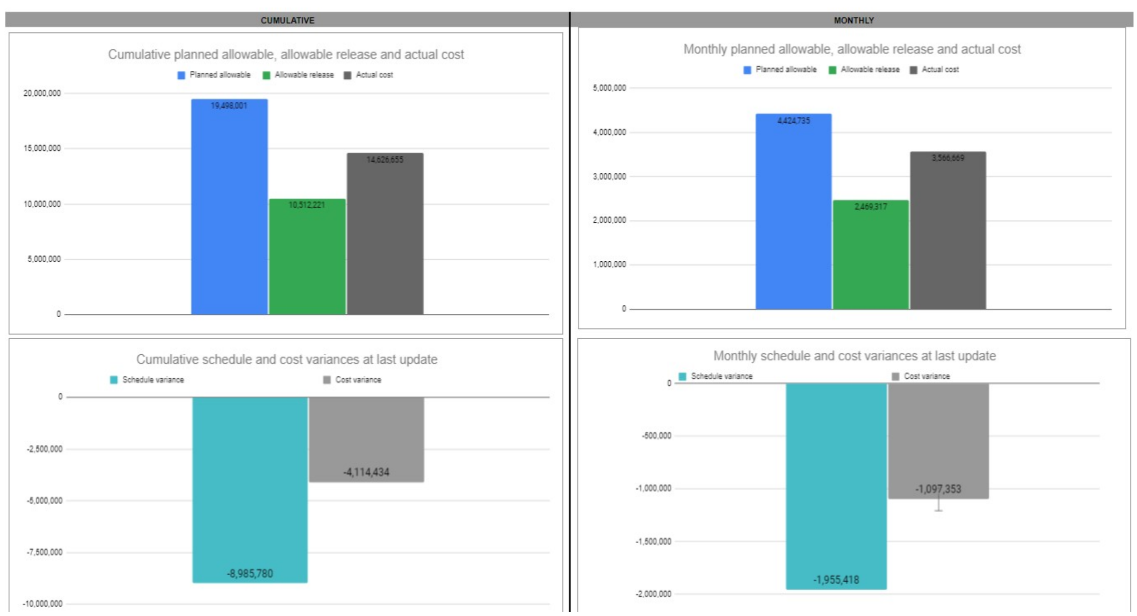


Figure 20: Labour histograms

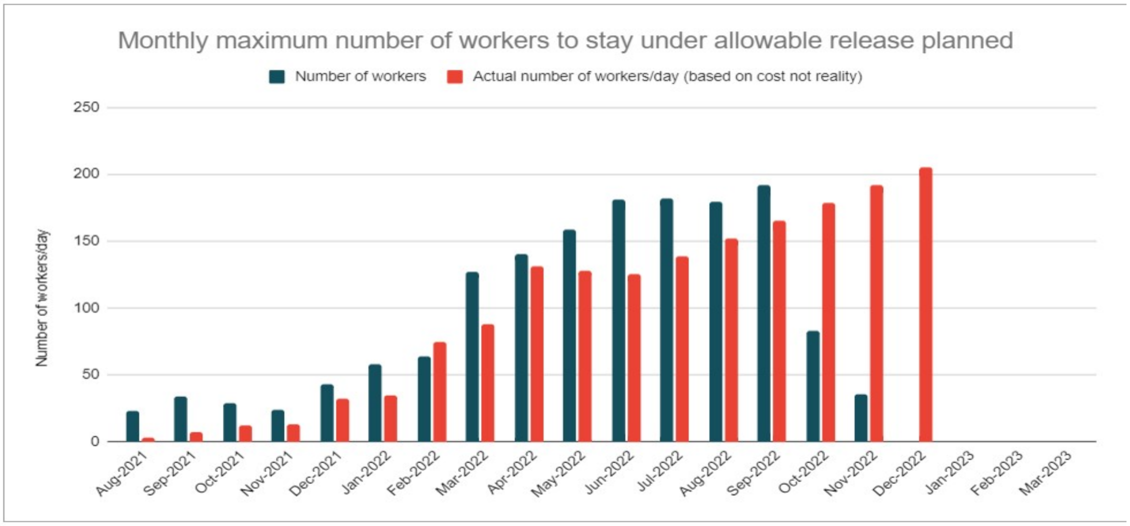


Figure 21: Workers

7 Validation

The validation of the tool is divided in two ways as it was discussed in the methodology. Moreover, the design brief presented in table 3 was used to support the validation as well. This section presents both validations.

The unstructured interviews were done weekly, they were part of the validation iteration process which was discussed previously. The interviews served to validate five key elements which namely, the data collection, the activity distribution, the forecast, the reliability and the convenience to use the tool. The components which have been validated are displayed in the table 4.

Table 4: Validation for the five key elements of the tool

Data collection	**Activity distribution**	**Forecast**	**Reliability**	**Convenience**
Planned allowables	Monthly	Planned progress	Close to reality	Ease of use
Planned progress	Cumulative	Actual cost		Adaptable
Actual cost		Allowable release		
Allowable release				

The validation of the forecast is done by holding 20% of the available data which represents two months. The months chosen are the last two months of available data: April and May. This validation is using the total cumulative amount of the project which consists of all the project categories: labour, materials, transport, sub-contractors, plant and equipment and others. The forecasts analysed are the progress, the cost and the allowable release forecasts. The results are shown in table 5.

Table 5: Validation for the months of April and May

	April				May			
Data analysed	***Actual (MUR)***	***Forecast (MUR)***	***Error***	***Percentage of error***	***Actual (MUR)***	***Forecast (MUR)***	***Error***	***Percentage of error***
Progress	118,657,889	118,397,735	260,154	0.2%	147,628,673	147,628,673	0	0%
Cost	99,910,401	95,172,590	4,737,811	4.7%	120,592,860	127,167,360	-6,574,948	-5.5%
Allowable release	79,152,412	75,846,990	3,305,422	4.2%	99,806,076	94,715,897	5,090,179	5.1%

The accepted marge of error by the project manager is of 5%. Most of the resulting data are within this range. However, it can be observed that for the month of may which is an estimation further in time, the tool performs worse for the cost. Nevertheless, because the cost estimated is higher than the actual one, it is having a lesser negative impact. Indeed, it is better to overestimate the cost of a project than to underestimate it as it ensures that enough money is available to complete the project without a cost overrun. Thus, the small deviation from the accepted error percentage is tolerated even though the tool could be improved to perform even better.

8 Results and analysis

8.1 Guideline for tool application in construction project

This sub-section provides insight on how to apply the tool in practice.

For each project's task, the schedule dates of start and end are to be added to the tool. The different allowable that are linked to the tasks must be added to the sheet. This allowable consists of the total amount reserved for the task's duration. The allowable are: labour, materials, transport, plant and equipment, sub-contractors and then the allowable which do not fit in any of those categories are included in the *other* category. The project progress is included as well.

The tool calculates the planned duration of the task and then, the planned weighted percentage of task done per month.
This allows to provide the different planned allowable amount divided for each month of the task's duration together with the planned project progress.

It is displayed in a table as shown in figure 22.

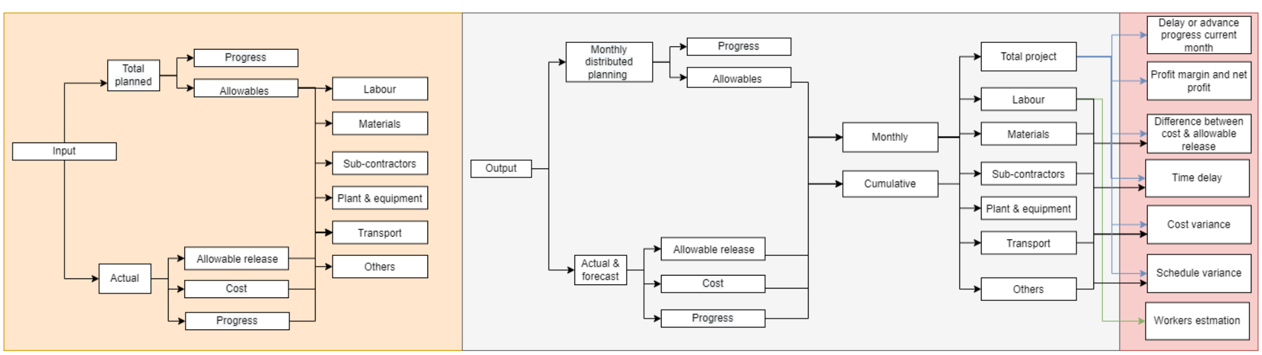


Figure 22: Input and output of project control tool

A guideline is provided in the tool. It is divided in three parts: input, automatic fill and automatic output as it can be seen in the figure 23. It is also divided in sheets as it was discussed in the section 5.3, hence the two first sheets require an input from the user while the rest does not need any manual input. The cell where the component is present is given on the right side of each component.

Guideline to use the tool

Planning distribution sheet

Input	Cells	Automatic fill	Cells	Automatic output
Start project date d-m-y *Start on a Monday*	B3	Total task allowable	E6:E...	**Distributed activity over time duration (Below distribution table)**
Project duration in months	B4	Duration in months *Even if less than 1 month of work (e.g.16 days), it displays 1 month durai*	O6:O	Planned progress
Task names	A6:A...	Hidden columns P to U:		Planned total allowable
If task header -> Insert H in column	B6:B...	Number of month & year (start, end date)	P6:S...	Labour allowable
Zones *If there is no zone in project, leave it empty*	C6:C...	Weighted percentage of task for each month: 1/duration No weighted % for total tasks If you want total only: instead of "H" in R5 put "" and drag down	T6:...	Materials allowable
Table of planned progress and allowable in MUR		Formula as written for task 1 in Google Sheet: =IF(B6<>"H",1/S6,)		Transport allowable
Project progress	D6:D...	Verification that weighted percentage is correctly displayed for all tasks during the time period *In red if different than 100%*	U6:U...	Plant & equipment allowable
Labour allowable	F6:F...	**Distribution table**		Sub-contractors allowable
Materials allowable	G6:G	Months & years of distribution table: rows 1,2 & 5 from column W		Others allowable
Transport allowable	H6:H...	Weighted percentage of task for each month of its duration If table size si changed: drag formula from cell W6 to new table size		**1) Monthly distributed activity in MUR**
Plant & equipment allowable	I6:I...			**2) Cumulative distributed activity in MUR**
Sub-contractors allowable	J6:J...			**3) Cumulative distributed activity in %**
Other allowable	K6:...			
Duration (working days)	L6:L...			
Start & end date of task d-m-y	M6:M... &N6:...N			

Actual data sheet

Input	Cells	Automatic fill	Cells	Automatic output
Insert actual month update from displayed dated *It changes the actual update automatically for the other sheets*	F1	**Monthly**		Cumulative allowable progress in % for each allowable *([labour,...] allowable release / total [labour,...] allowable release)*
Monthly actual data of project until current month update in MUR		Project progress in % *(Monthly progress / Total progress)*	E9:...	
Project progress	E8:...	**Cumulative**		
Labour allowable release and cost	E10:... & E11:...	Project progress in MUR & in % *(Cumulative progress / Total progress)*	E26:... & E27:...	
Materials allowable release and cost	E12:... & E13:...	Labour allowable release and cost	E28:... & E29:...	
Transport allowable release and cost	E14:... & E15:...	Materials allowable release and cost	E30... & E31:...	
Plant & equipment allowable release and cost	E16:... & E17:...	Transport allowable release and cost	E32:... & E33:...	
Sub-contractors allowable release and cost	E18:... & E19:...	Plant & equipment allowable release and cost	E34:... & E35:...	
Others allowable release and cost	E20:... & E21:...	Sub-contractors allowable release and cost	E36:... & E37:...	
Total allowable release and cost	E22:... & E23:...	Others allowable release and cost	E38:... & E39:...	
Monthly & cumulative forecast project data		Total allowable release and cost	E40:... & E41:...	
Find the slope (m) for each allowable release (labour, materials,...) and the related actual cost - Select the last allowable update (yb) input and subtract it to the previous value (ya) - Select the last allowable cumulative % progress (xb) and subtract it to the previous one (xa) **m=(yb-ya)/(xb-xa)** **Find the intercept for each allowable (labour, materials,...)** - Select the last allowable update (yb) and then apply the following formula: **b= yb-m*xb**				

Total sheet

Input	Cells	Automatic fill	Cells	Automatic output
		Monthly & cumulative tables		**Monthly & cumulative tables**
		Planned progress %		Progress variance (MUR) *(Actual progress-planned progress)*
		Actual Progress %		Cost variance (MUR) *(allowable release-cost)*
		Planned progress		Profit margin (MUR) *(actual progress-cost)*
		Actual progress (MUR)		Net profit margin (%) *(Actual progress-actual cost)/Actual progress*
		Planned total allowable (MUR)		Schedule variance (MUR) *(allowable release-planned allowable)*
		Allowable release (MUR)		**Cumulative**
		Actual cost (MUR)		Forecast Progress (MUR)
				Forecast cost (MUR)
				Forecast allowable release (MUR)
				Monthly & cumulative last update tables *Those tables only display the KPI of the last update day to fill the graphs*
				Graphs of cumulative and monthly performance:
				Actual progress against planned progress
				Actual progress, allowable release and cost

Allowables sheets

Input	Cells	Automatic fill	Cells	Automatic output
		Monthly & cumulative tables		**Monthly & cumulative tables**
		Planned progress allowable %		Cost variance (MUR) *(allowable release-cost)*
		Actual Progress allowable %		Schedule variance (MUR) *(allowable release-planned allowable)*
		Planned allowable		**Monthly & cumulative last update tables** *Those tables only display the KPI of the last update day to fill the graphs*
		Actual allowable release (MUR)		**Graphs of cumulative and monthly performance:**
		Actual cost (MUR)		Planned allowable, allowable release and actual cost
				Schedule and cost variances at last update

Figure 23: Guideline

8.2 Recommendation and discussion on case study results

The results obtained through the analysis show that the project is expected to be on schedule at its completion. However, it can be better observed on the figure 15 that the project has a small delay. This delay represents approximately one or two weeks of work.The tool displays the time periods only by month, hence the time step of the tool cannot have smaller time step than one month.
The progress at completion of the project corresponds to the planned amount. However, it can be seen that along the entire project timeline, the difference between the planned and the actual progress are almost null. The main reason for this is that the project schedule was updated recently and it was included to the tool.
The tables 6 provide information on the cost variance and the schedule variance. The planned and estimated values of the allowable release are also displayed as well as the project's cost. The table 7 comprises the progress, the profit margin and the time difference with the planning.

Table 6: Schedule and cost variance at completion

Category	Planned allowable release	Estimated allowable release	Schedule variance	Cost	Cost variance
Overall project	260,996,367	249,399,096	11,597,271	228,432,978	-20,966,118
Labour	43,248,624	43,248,624	0	61,910,961	-18,662,338
Materials	86,839,896	86,839,896	0	71,815,157	15,024,739

Table 7: Progress and profit margin at project completion

At completion	Progress (MUR)	Profit margin (MUR)	Time delay (month)
	228,432,978	78,653,852	0

The actual performance for the overall project is given in figure 24. For the labour, it is given in figure 25 and for materials in figure 26.

Monthly last update	
Month-Year	May-2022
Progress delay/ahead	Progress delay
Progress variance	-260,155
Cost overrun/underrun	Cost overrun
Cost variance *(allowable release-cost)*	-28,796
Profit / No profit	Profit
Profit margin *(actual progress-cost)*	8,288,325
Net profit margin *(Actual progress-actual cost)/Actual progress*	29%
Ahead/behind scheduled allowable release	Schedule delay
Schedule variance *(allowable release-planned allowable)*	-3,687,132
Planned progress %	9%
Actual Progress %	9%
Planned allowable	24,340,795
Allowable release	20,653,663
Planned progress	29,230,939
Actual progress (MUR)	28,970,784
Actual cost	20,682,459

(a) Monthly

Cumulative last update	
Month-Year	May-2022
Progress delay/ahead	Progress delay
Progress variance	-3,378,091
Cost overrun/underrun	Cost overrun
Cost variance *(allowable release-cost)*	-20,786,784
Profit / No profit	Profit
Profit margin *(actual progress-cost)*	27,035,813
Net profit margin *(Actual progress-actual cost)/Actual progress*	18%
Ahead/behind scheduled allowable release	Schedule delay
Schedule variance *(allowable release-planned allowable)*	-11,403,145
Planned progress %	46%
Actual Progress %	45%
Planned allowable	111,209,221
Allowable release	99,806,076
Planned progress	151,006,765
Actual progress (MUR)	147,628,673
Actual cost	120,592,860

(b) Cumulative

Figure 24: Project last update of overall project performance

Montlhly last update	
Month-Year	May-2022
Planned progress %	10%
Actual progress allowable %	6%
Planned allowable	4,424,735
Allowable release	2,469,317
Actual cost	3,566,669
Ahead/behind scheduled allowable release	Schedule delay
Schedule variance *(allowable release-planned allowable)*	-1,955,418
Cost overrun/underrun	Cost overrun
Cost variance *(allowable release-cost)*	-1,097,353

(a) Monthly

Cumulative last update	
Month-Year	May-2022
Planned progress %	45%
Actual progress allowable %	24%
Planned allowable	19,498,001
Allowable release	10,512,221
Actual cost	14,626,655
Ahead/behind scheduled allowable release	Schedule delay
Schedule variance *(allowable release-planned allowable)*	-8,985,780
Cost overrun/underrun	Cost overrun
Cost variance *(allowable release-cost)*	-4,114,434

(b) Cumulative

Figure 25: Project last update of labour performance

Montlhly last update	
Month-Year	5-2022
Planned progress %	14%
Actual progress allowable %	11%
Planned allowable	12,073,789
Allowable release	9,400,119
Actual cost	5,621,949
Ahead/behind scheduled allowable release	Schedule delay
Schedule variance *(allowable release-planned allowable)*	-2,673,670
Cost overrun/underrun allowable release	Cost underrun
Cost variance *(allowable release-cost)*	3,778,170

(a) Monthly

Cumulative last update	
Month-Year	May-2022
Planned progress %	43%
Actual progress allowable %	32%
Planned allowable	37,225,596
Allowable release	27,900,134
Actual cost	36,564,926
Ahead/behind scheduled allowable release	Schedule delay
Schedule variance *(allowable release-planned allowable)*	-9,325,463
Cost overrun/underrun allowable release	Cost overrun
Cost variance *(allowable release-cost)*	-8,664,792

(b) Cumulative

Figure 26: Project last update of material performance

The schedule which was added to the tool was updated by the management team so that the project will finish on the desired time and cost. Thus, it is not possible to give any recommendation on the results as they correspond to the planning.

8.3 Tool discussion

This sub-section is divided in two parts. The first part presents the challenges to apply the tool while the second part provides recommendations.

Challenges

One requirement of the tool which appeared after one cycle of the TAR methodology was to include for the project manager of the case study, the required number of workers based on the labour allowable planned. However, the tool used only one average salary when the amount actually differs depending on overtimes and other criteria. Thus, when the actual cost of labour is compared, a difference can be seen not only because the labour used is different from the planned ones but also because of the variations that were not included. Hence, the results of this analysis are giving an indication to the project manager but they could be improved to provide more reliable results.

Towards the end of the forecasts, in case that the project is not perfectly on time, as the planned progress is supposed to be of 100 %, the tool then takes the last forecast progress and adds to it the difference of progress between the planned progress and the actual forecast progress. Hence, the tool adds the difference of progress directly to the actual progress. This means that if no changes of performance are done to reduce the delay, it expects an acceleration of the project towards the end to realize the activity missing in one month. However, this is not always the case in reality if the delay is too considerable.

The input of the tool in this project required some changes during the time of this research. Those changes were due to the realization of a new task's schedule as the project was facing a delay, the management team decided to change the schedule to reduce the delay and to find the new finishing date of the project. However, this required changes in the tool not only in terms of time but also in terms of task's name. Moreover, at the beginning of the design the task's had to be re-organised for the tool in categories like earthworks or drainage. However, if the schedule organised the tasks as such, this was not exactly the case in the expense control of the company. Furthermore, as the tool was newly developed, to not change the current expense control by mistake, the new tool is not connected to it directly which could make it unnecessary time consuming to add or change data.

Recommendations

The tool could be improved by adding new functionalities to it. One that has been added already was the number of workers required as discussed in the section 5. However, its reliability could be improved. One way to do so would be to combine the current tool that provides the actual cost of workers on similar projects and make estimations of the cost of workers for some tasks and then include it to this tool.

The forecast towards the end of the construction project phase could be improved. A suggestion would be to propose the maximum amount of activity that can be done in one month in case of delays and then adapt the tool to apply it at the required time period instead of all the delay at the end. Hence, if the project manager decides to increase the performance at a certain moment in time this can be adapted either before the planned end or after. Thus, the tool instead of only showing a forecast based on the last cumulative performance update, it could also include planned acceleration to reduce the unforeseen delays.

To reduce time lost due to changes in the expense control, the current expense control should be directly linked to the newly developed tool. It will allow to reduce time lost but also possible errors. To do so, it would be advised to organise the task's categories in a way that any changes in the expense control would be inserted in the new project tool without an additional intervention. Furthermore, like it was seen in this case study, several new schedules might be done during the construction phase. This would lead to changes in the project control tool, however, to reduce the confusion while updating it, it could be better to maintain main categories without changing them along the way of the construction phase.

The accuracy of the tool for the forecast should be further verified. In fact, the tool must be further validated once the project is completed. The validation was only realized for a close forecast. However, it would be necessary to validate the tool for longer forecasts of several months to see to what extent the tool gives a valid forecast. Moreover, having more data points would give additional randomness to the validation process, thus, it would improve it validity. This final validation will allow to give a precise idea of the deviation of the results output from reality for future projects.

9 Further research

Most of the initial objectives of the tool were met. However, as discussed earlier the tool provided an updated schedule. This prevented this research to give an analysis of the results on the MP project. Nevertheless, the main purpose of this research was to support the project managers of GCC. Another study could be done to see if this tool could be further developed to fit and to add support to other companies' project control process. The forecast at the end of the project would benefit from a new strategy to give a more realistic forecasting. The forecast could add new features so that it could be adapted for example with the impact of corrective actions on the forecast. Furthermore, the inclusion of different risk scenario could provide a great addition to the tool as it will give an indication to project managers of the impact on certain project's risks on the project.

10 Conclusion

This study followed a TAR methodology to answer the research questions. The structure of this method allowed to use the research to answer the host organisation's requirements while using the collaboration for validating the project control tool.

The literature review revealed past research and methods used for controlling project's cost and time but also forecasting methods. It enabled to select the most suitable forecasting method for this study, namely a linear forecasting based on the last cumulative project performance. Furthermore, it highlighted the importance of KPI and the ones which should be included in the design of the project control tool. Furthermore, as part of the TAR methodology, the MP project served as a case study to validate the tool design and to answer the project manager's requirements. Hence, the data input of the tool were imported from this existing project. On another hand, unstructured interviews were realized throughout the research duration to define design requirements. The design of the tool used a systems engineering analysis. Thus, a design brief coming from the unstructured interviews was done. The elements coming from the literature review and the interviews were then included to a FAST diagram and resulted in objects. Resulting from the requirement analysis, the selected KPI for the tool were the following: project progress, cost and schedule variances, profit and net profit margin. Other design requirements were included. Those were about basic functions such as forecasting costs but also with supporting functions such as providing reliability to the tool. Furthermore, the interviews also served to validate the data output of the project control tool. The tool was implemented based on the requirements analysis. The project control tool presented some challenges. Those were addressed by proposing solutions to overcome them and further improve the control tool.

To answer one of the research sub-question but also one of the project manager's requirement, a step by step guideline to use the tool in practice for project manager's at GCC was given.

Throughout the project duration, a new project schedule was created and the tool was updated again based on this new schedule. The re-schedule was done so that the project would finish on time. Thus, the first sub-question of the second research question was not answered. In fact, due to the update the project was now almost perfectly on time and without cost overrun, hence no recommendation could be made. However, the actual performance and forecasted performance of the case study were still given based on the KPI selected. The tool was validated and performs according to the requirements of the project manager of the host organisation. Finally, this study gave an additional support to GCC to control actual and forecasted cost, time and progress for the MP project but also their future constructions projects.

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11 Appendix

11.1 Appendix A

The tables 27 and 28 contain the monthly and cumulative data output of the project.

Monthly and cumulative tables

Monthly										
Month-Year	Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022
Planned progress %	2%	6%	2%	2%	3%	4%	4%	6%	7%	9%
Actual Progress %	0%	4%	3%	5%	5%	4%	5%	6%	5%	9%
Planned progress	6,350,417	18,926,939	7,944,790	6,664,309	10,762,537	13,831,396	14,597,763	20,555,943	22,141,731	29,230,939
Actual Progress (MUR)	0	12,068,861	8,234,540	16,572,371	16,398,610	14,693,230	15,037,551	18,338,886	17,313,841	28,970,784
Planned total allowable	3,540,321	11,231,725	4,989,750	3,825,677	7,551,339	10,341,211	11,037,908	16,454,435	17,896,061	24,340,795
Allowable release	5,092,230	4,545,079	3,732,077	7,632,146	6,416,815	10,988,827	14,593,502	11,837,962	14,313,774	20,653,663
Actual cost	1,321,833	3,191,112	2,238,033	5,083,878	13,177,712	10,877,977	20,543,049	20,072,856	23,403,951	20,682,459
Progress delay/ahead	Progress delay	Progress delay	Progress ahead	Progress ahead	Progress ahead	Progress ahead	Progress ahead	Progress delay	Progress delay	Progress delay
Progress variance	-6,350,417	-6,858,078	289,750	9,908,061	5,636,073	861,833	439,789	-2,217,057	-4,827,890	-260,155
Cost overrun/underrun	Cost underrun	Cost underrun	Cost underrun	Cost underrun	Cost overrun	Cost underrun	Cost overrun	Cost overrun	Cost overrun	Cost overrun
Cost variance *(allowable release-cost)*	3,770,397	1,353,967	1,494,044	2,548,268	-6,760,897	110,851	-5,949,547	-8,234,894	-9,090,177	-28,796
Profit / No profit	No profit	Profit	Profit	Profit	Profit	Profit	No profit	No profit	No profit	Profit
Profit margin *(actual progress-cost)*	-1,321,833	8,877,748	5,996,507	11,488,492	3,220,898	3,815,253	-5,505,498	-1,733,971	-6,090,110	8,288,325
Net profit margin *(Actual progress-actual cost)/Actual progress*	#DIV/0!	73.56%	72.82%	69.32%	19.64%	25.97%	-36.61%	-9.46%	-35.17%	28.61%
Ahead/behind scheduled allowable release	Schedule ahead	Schedule delay	Schedule delay	Schedule ahead	Schedule delay	Schedule ahead	Schedule ahead	Schedule delay	Schedule delay	Schedule delay
Schedule variance *(allowable release-planned allowable)*	1,551,909	-6,686,646	-1,257,674	3,806,469	-1,134,523	647,617	3,555,595	-4,616,473	-3,582,287	-3,687,132

Monthly								
Month-Year	Jun-2022	Jul-2022	Aug-2022	Sep-2022	Oct-2022	Nov-2022	Dec-2022	Jan-2023
Planned progress %	9%	8%	9%	12%	8%	7%	1%	
Actual Progress %								
Planned progress	31,149,320	27,573,823	28,358,792	40,459,418	25,341,273	22,418,992	1,744,564	
Actual Progress (MUR)								
Planned total allowable	26,084,778	22,834,326	23,547,934	34,548,503	20,804,735	20,380,902	1,585,968	
Allowable release								
Actual cost								
Progress delay/ahead								
Progress variance								
Cost overrun/underrun								
Cost variance *(allowable release-cost)*								
Profit / No profit								
Profit margin *(actual progress-cost)*								
Net profit margin *(Actual progress-actual cost)/Actual progress*								
Ahead/behind scheduled allowable release								
Schedule variance *(allowable release-planned allowable)*								

Figure 27: Monthly table of overall project performance

Monthly last update												
Month-Year										May-2022		
Progress delay/ahead										Progress delay		
Progress variance										-260,155		
Cost overrun/underrun										Cost overrun		
Cost variance *(allowable release-cost)*										-28,796		
Profit / No profit										Profit		
Profit margin *(actual progress-cost)*										8,288,325		
Net profit margin *(Actual progress-actual cost)/Actual progress*										29%		
Ahead/behind scheduled allowable release										Schedule delay		
Schedule variance *(allowable release-planned allowable)*										-3,687,132		
Planned progress %										9%		
Actual Progress %										9%		
Planned allowable										24,340,795		
Allowable release										20,653,663		
Planned progress										29,230,939		
Actual progress (MUR)										28,970,784		
Actual cost										20,682,459		

Figure 28: Table of monthly last update on overeall project performance

11.2 Appendix B

This appendix shows an overview of the tool's sheets. Even though the materials, transport, plant and equipment, other and sub-contractors sheets exist, they are not included as they are not analysed in this research.

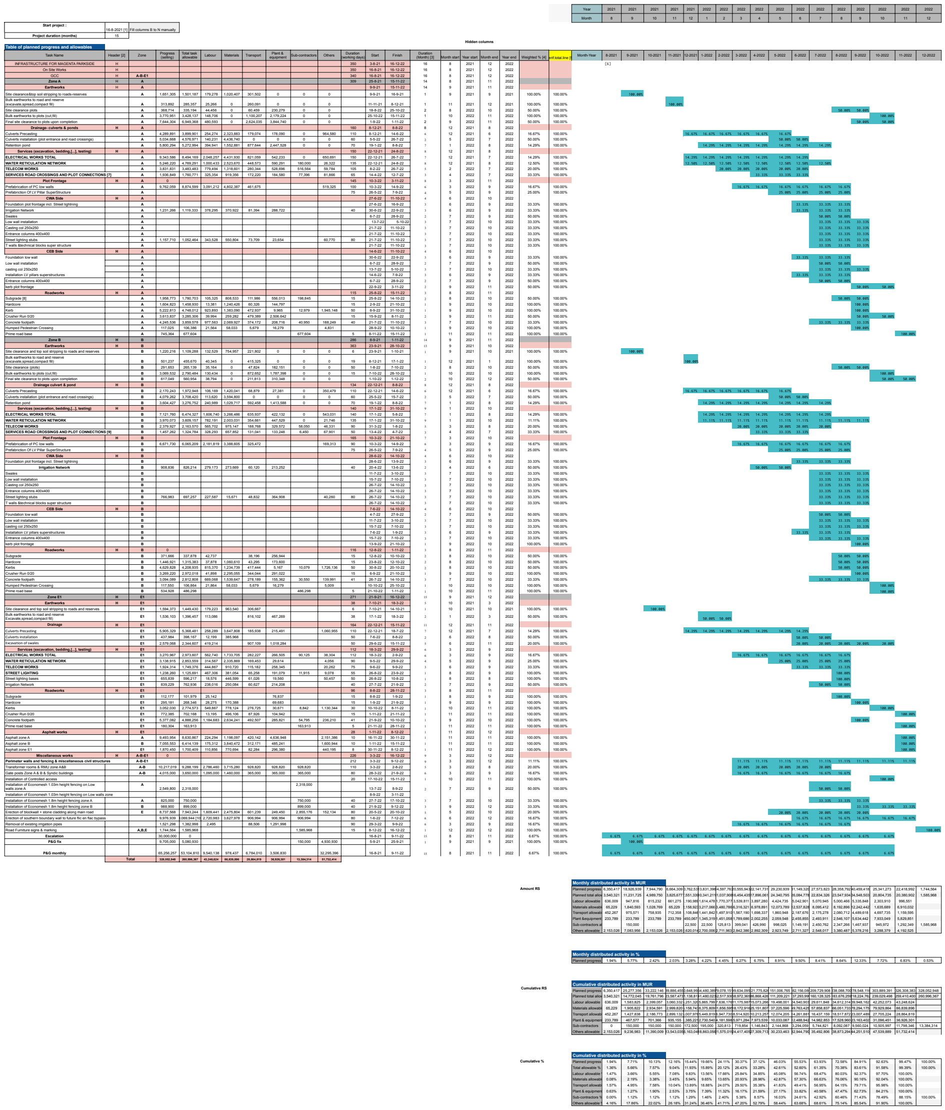

Figure 29: Planning distribution as displayed in Google Sheet

Actual update	May-2022

Month-Year	Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022	Jun-2022	Jul-2022	Aug-2022	Sep-2022	Oct-2022	Nov-2022	Dec-2022	Jan-2023	Feb-2023	Mar-2023	Apr-2023	May-2023	Jun-2023	Jul-2023

Monthly & cumulative actual project data

Total progress planned	328,052,948	Monthly			Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022
			Progress		0	12,068,861	8,234,540	16,572,371	16,398,610	14,693,230	15,037,551	18,338,886	17,313,841	28,970,784
			Progress %		0%	4%	3%	5%	5%	4%	5%	6%	5%	9%
Total allowable release planned	43,248,624		Labour	Release	0	704,007	649,825	808,819	1,105,818	847,642	1,169,617	1,066,400	1,690,777	2,469,317
				Cost	91,378	208,869	342,547	375,788	889,452	960,579	2,081,030	2,449,330	3,661,012	3,566,669
	86,839,896		Materials	Release	0	65,229	65,229	984,508	4,311,426	3,297,756	5,802,448	1,978,582	1,994,836	9,400,119
				Cost	225,122	361,940	184,080	859,065	6,275,939	3,629,097	6,044,793	5,137,405	8,225,535	5,621,949
	28,864,819		Transport	Release	0	565,374	463,460	1,312,488	1,448,854	2,221,070	240,781	662,213	1,781,912	2,431,947
				Cost	96,932	119,943	161,381	730,493	1,294,340	1,469,271	2,272,356	1,770,771	1,860,612	2,599,852
	36,926,301		Plant & equipment	Release	0	1,057,441	400,537	2,373,305	1,199,801	2,203,870	1,401,871	764,568	1,325,096	2,434,650
				Cost	50,823	349,644	527,208	1,112,687	2,899,463	2,990,696	4,866,629	3,435,984	5,773,338	6,339,420
	13,384,314		Sub-contractor	Release	150,000	0	0	0	0	0	3,659,311	4,452,274	3,956,164	0
				Cost	47,360	11,800	0	27,426	331,200	343,195	3,746,536	5,701,170	2,168,388	865,839
	51,732,414		Others	Release	0	0	0	0	55,758	214,636	183,765	803,349	1,326,065	1,543,910
				Cost	0	0	0	0	0	0	0	0	0	0
	260,996,367		Total	Release	5,092,230	4,545,079	3,732,077	7,632,146	6,416,815	10,988,827	14,593,502	11,837,962	14,313,774	20,653,663
				Cost	1,321,833	3,191,112	2,238,033	5,083,878	13,177,712	10,877,977	20,543,049	20,072,856	23,403,951	20,682,459

Total progress planned	328,052,948	Cumulative			Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022
			Progress		0.00	12,068,860.55	20,303,400.32	36,875,770.84	53,274,381.03	67,967,610.89	83,005,162.20	101,344,047.99	118,657,889.39	147,628,673.41
			Progress %		0%	4%	6%	11%	16%	21%	25%	31%	36%	45%
Total allowable release planned	43,248,624		Labour	Release	0	704,007	1,353,832	2,162,652	3,268,469	4,116,112	5,285,728	6,352,128	8,042,905	10,512,221
				Cost	91,378	300,247	642,795	1,018,583	1,908,035	2,868,614	4,949,644	7,398,973	11,059,986	14,626,655
	86,839,896		Materials	Release	0	65,229	130,458	1,114,966	5,426,392	8,724,149	14,526,597	16,505,179	18,500,015	27,900,134
				Cost	225,122	587,062	771,142	1,630,207	7,906,146	11,535,243	17,580,036	22,717,442	30,942,976	36,564,926
	28,864,819		Transport	Release	0	565,374	1,028,834	2,341,322	3,790,175	6,011,245	6,252,026	6,914,239	8,696,151	11,128,098
				Cost	96,932	216,875	378,256	1,108,749	2,403,090	3,872,361	6,144,716	7,915,488	9,776,099	12,375,951
	36,926,301		Plant & equipment	Release	0	1,057,441	1,457,978	3,831,284	5,031,085	7,234,954	8,636,825	9,401,393	10,726,489	13,161,139
				Cost	50,823	400,468	927,676	2,040,363	4,939,826	7,930,522	12,797,150	16,233,134	22,006,472	28,345,891
	13,384,314		Sub-contractor	Release	150,000	150,000	150,000	150,000	150,000	150,000	3,809,311	8,261,585	12,217,749	12,217,749
				Cost	47,360	59,160	59,160	86,586	417,786	760,981	4,507,517	10,208,687	12,377,075	13,242,914
	51,732,414		Others	Release	0	0	0	0	55,758	270,393	454,159	1,257,508	2,583,573	4,127,484
				Cost	0	0	0	0	0	0	0	0	0	0
	260,996,367		Total	Release	5,092,230	9,637,308	13,369,385	21,001,531	27,418,347	38,407,174	53,000,676	64,838,638	79,152,412	99,806,076
				Cost	1,321,833	4,512,945	6,750,978	11,834,856	25,012,568	35,890,545	56,433,594	76,506,450	99,910,401	120,592,860

Cumulative forecast project data

Progress based on allowable		Aug-2021	Sep-2021	Oct-2021	Nov-2021	Dec-2021	Jan-2022	Feb-2022	Mar-2022	Apr-2022	May-2022
	Labour	0%	2%	3%	5%	8%	10%	12%	15%	19%	24%
	Materials	0%	0%	0%	1%	6%	10%	17%	19%	21%	32%
	Transport	0%	2%	4%	8%	13%	21%	22%	24%	30%	39%
	Plant & equipment	0%	3%	4%	10%	14%	20%	23%	25%	29%	36%
	Sub-contractor	1%	1%	1%	1%	1%	1%	28%	62%	91%	91%
	Others	0%	0%	0%	0%	0%	1%	1%	2%	5%	8%

Labour	Forecast allowable	m	43,248,624
		b	0
	Forecast cost	m	62,468,110
		b	-557,148

Transport	Forecast allowable	m	28,864,819
		b	0
	Forecast cost	m	30,857,688
		b	479,553

Sub-contractor	Forecast allowable	m	13,384,314
		b	0
	Forecast cost	m	2,929,267
		b	10,568,959

Materials	Forecast allowable	m	86,839,896
		b	0
	Forecast cost	m	51,936,524
		b	19,878,633

Plant & equipment	Forecast allowable	m	36,926,301
		b	0
	Forecast cost	m	96,149,886
		b	-5,923,504

Others	Forecast allowable	m	
		b	
	Forecast cost	m	
		b	

Total cumulative	Forecast progress	m	328,052,948
		b	0
	Forecast cost	m	234,199,447
		b	15,199,649
	Forecast allowable	m	233,873,377
		b	-5,440,399

Figure 30: Actual data as displayed in Google Sheet

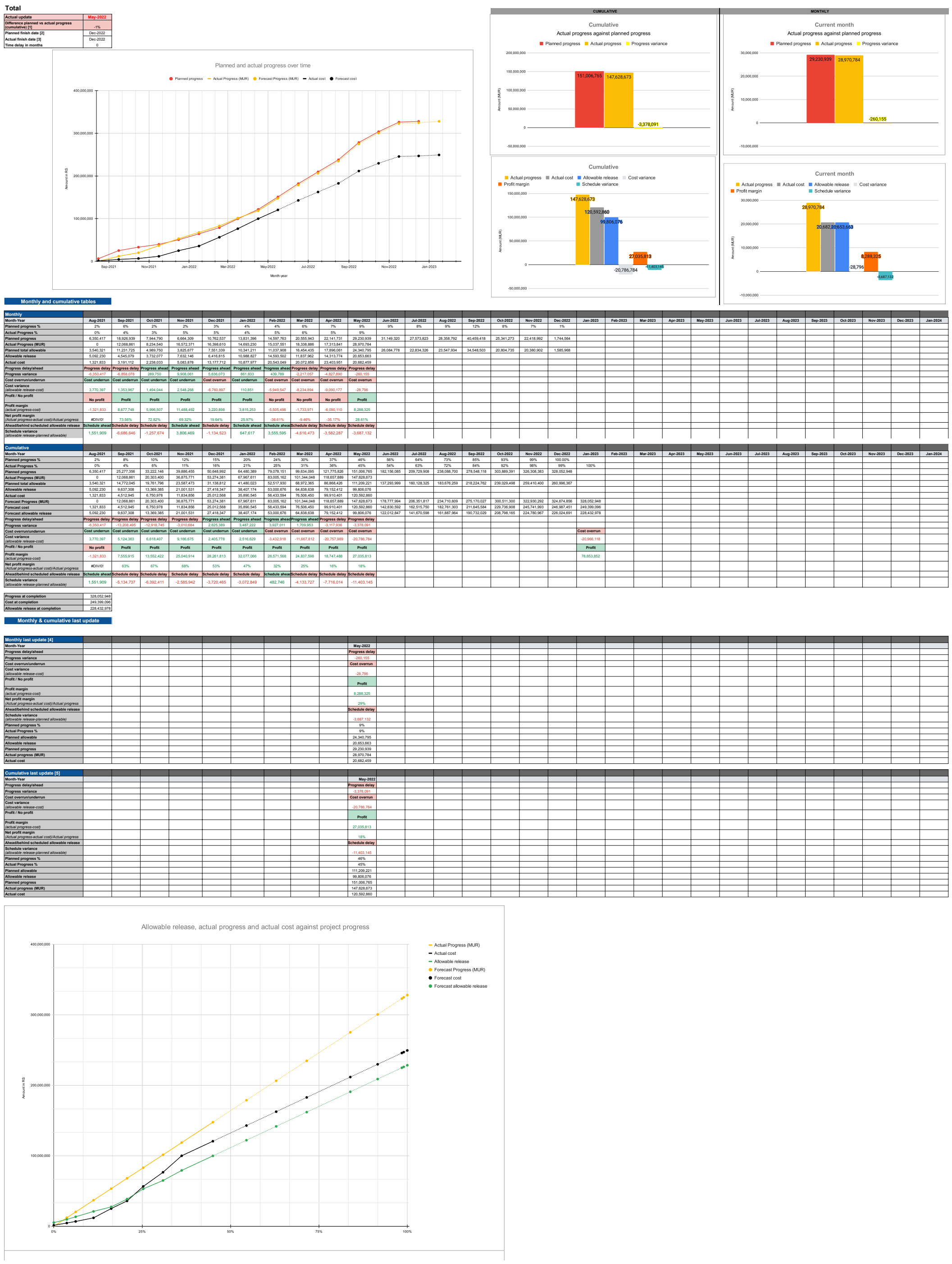

Figure 31: Total sheet as displayed in Google Sheet

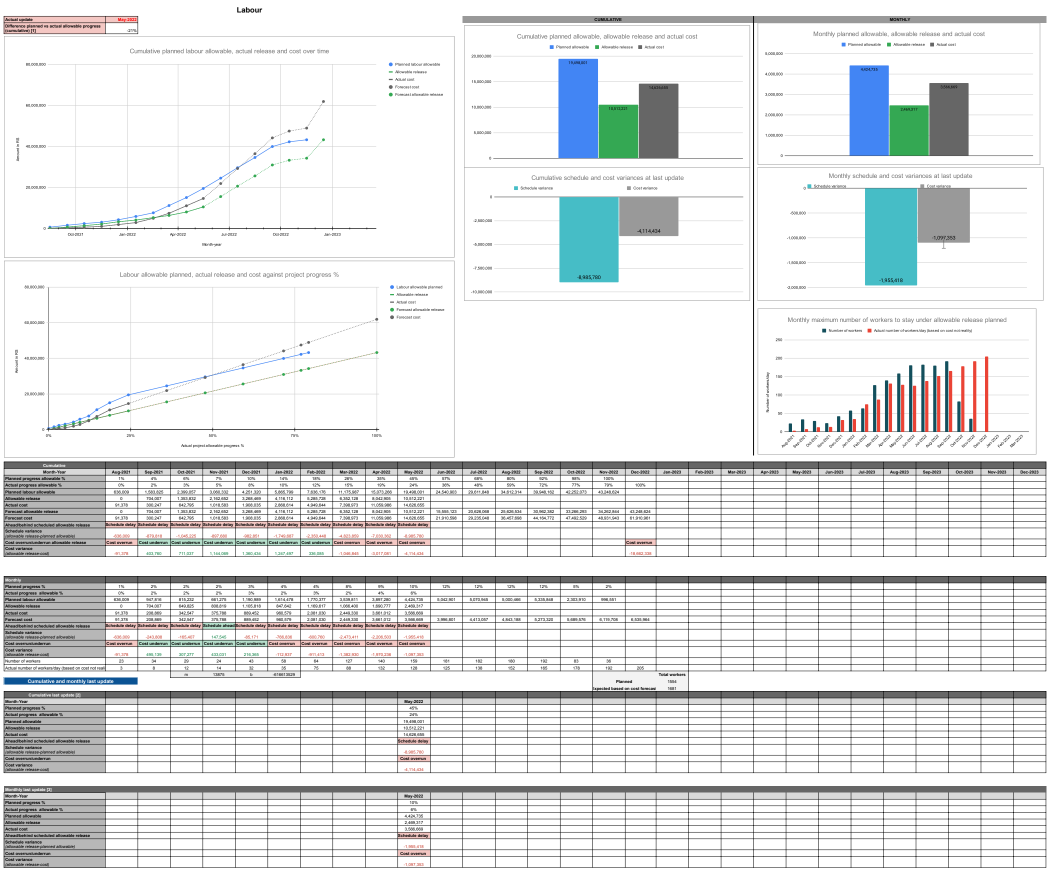

Figure 32: Labour sheet as displayed in Google Sheet

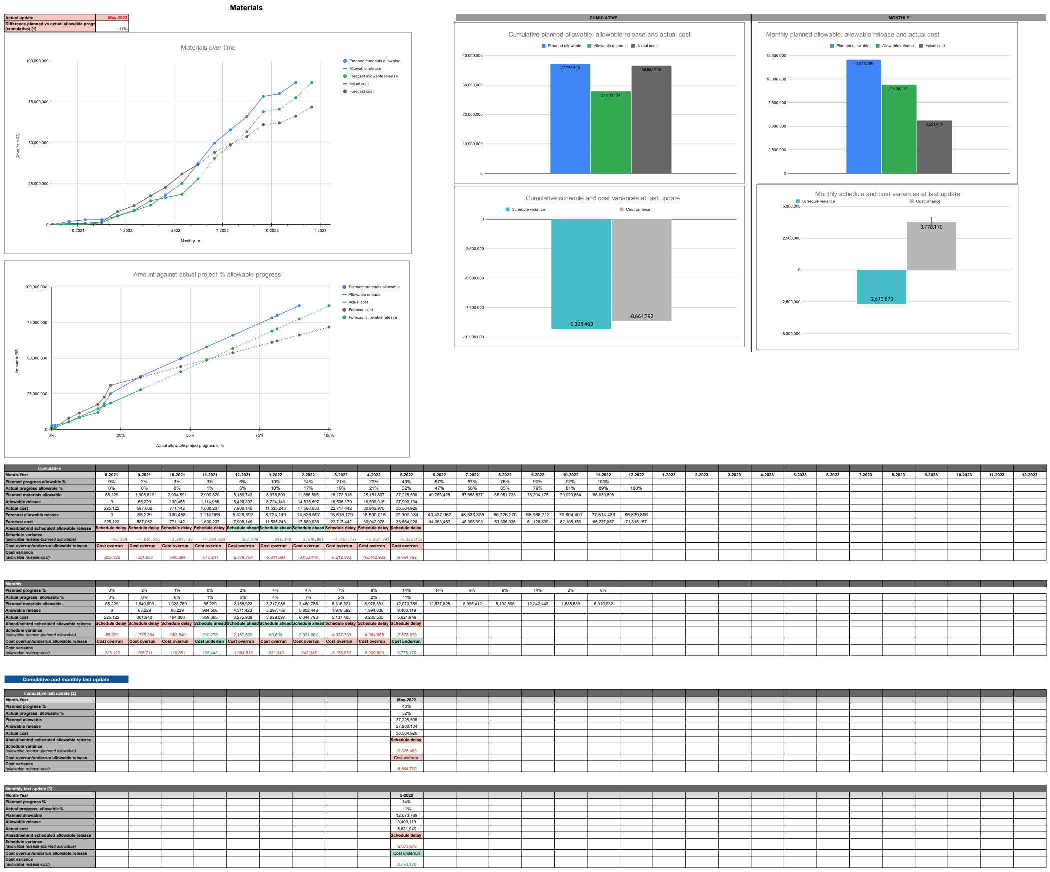

Figure 33: Materials sheet as displayed in Google Sheet