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PROJECT PLANNING & RESOURCE USAGE PREDICTION SYSTEM BASED ON THE BUILDING AND CONSTRUCTION INDUSTRY

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Abstract

Building construction is the process of constructing a building which can be single stored, or multi stored limited by a specific time frame and a budget. Building construction differs from the manufacturing industry because the manufacturing industry produces a huge number of similar items without a targeted purchaser while building and construction takes place on location for a known client. There for there is a special term called resource allocation in the construction industry where all the activities and tasks are based on those resources. In building construction, resources are classified in to material, plant and labour. Efficient usage of these resources will provide better results and it will reduce the cost. This research is about a software system especially made for building and construction industry which can track and monitor the performance/usage of resources.

***Keywords**:* Component: Geographical Positioning System; Overall Equipment Effectiveness; Total Productive Maintenance; Key Performance Indicator; Overall Labour Effectiveness; Total Effectiveness; Construction Project Micro Planning; Construction Task Duration Prediction; Supervisor Assistant.

1. Introduction

Heavy equipments are one of the key resources when it comes to building and construction industry. Most of the construction activities can be completed easily with the help of these machines. After allocating a machine to a particular construction task, there should be a way to monitor it. The system proposes customized algorithms based on Overall Equipment Effectiveness. Most of the machine monitoring solutions available in the market uses geographical positioning and geographical information acquisition to monitor machines.

OEE is a practicable standard, especially designed for manufacturing industry. When it comes to part analysis, if the OEE score is 100%, it implies manufacturing produces good parts [1]. But, when it comes to building and construction industry, this approach is not practically applicable since building construction is based on tasks but not on part analysis. OEE calculation is based on three parameters called Availability, Performance and Quality. Since OEE is made for machines in manufacturing industry, it cannot be directly applied for machines used in building and construction industry. Although Availability can be directly applicable to both the areas, performance analysis cannot be applicable to both. If the system can introduce a task as a part, manufacturing based performance algorithm can be directly applied [2]. But, it's not practical since a part cannot be considered as a task. Quality analysis is a quantitative parameter used in the manufacturing industry. When mapping it in to building and construction machines, there should be a way of questioning the machines behavior when performing the task and after executing it.

In a construction site, materials are very important to cost analysis of the project and also the planning the progress of the construction. These materials come in different forms. The materials can be liquids, solids or particles and their usage is different from material to material.

Their application differs from material to material and also the way these materials handle, transport and store differs. Each material has unique and different qualities. These unique and different qualities need to be tracked to find out the best material for a particular scenario. Wrong material type in the wrong application can be a disaster. The purpose of material prediction and rating system is to minimize the material wastage and manage material usage correctly and also to rate materials and their manufactures. For these predictions and ratings, required data will be collected through the manufacture product details specifications, internet resources, and construction site surveys and also through the representatives of particular products. Several number of materials are used in current industry but the proposed system considers few most wanted materials like cement, sand, tiles (flooring), roofing, ceiling and paints. The proposed system can be used to analyze particular construction work and it will predict the resource usage for that work, using the custom made algorithms that are going to provide more accurate results than existing systems. In some situations, users can use the rating system, which also can provide information about products, applications and have the capability of suggesting products for particular scenario. By using the proposed material prediction and rating system, the user can get a more accurate material prediction that will help in minimizing resource wastage, in optimizing usage, in saving money, in choosing the most suitable item for particular purpose.

The Main purpose of this module is identify the best worker for each task to do that worker previous data going to be used. Analyzing the previous data of the worker, worker going to be have a rate value for each task. Using overall labour effectiveness (OLE) can rate the worker according to some factors. Main factors are Availability, Performance and Quality.

These are the main factors also some other factors going to use for analyses the worker and rate them. When rating the worker according task they have done, the system will prompt some questioners to the supervisor and also the supervisor is going to have some standards for answer them easily. According to the supervisor given answer in each task, the worker will be rated. According to those rate value, the worker going to have an overall rate value. In rating, those factors are going to be customizable because every task has metrics to be prioritized. Considering the rate value system going to be suggest best worker for each task. Construction project planning is the most important stage of construction industry. Without proper project plan construction project can't successfully complete within allocated duration. In the current industry, project plan is created by the project manager. Therefore, planning strategies change one project manager to another because planning is done according to their experience. Plan and experience of one manager differs from another manager. When creating project plan, the project manager doesn't consider their previous performance of task. There is no proper way of predicting task duration, besides proposing to predict the task duration using man hour concept. Project managers can use task prediction durations when planning projects.

In the current construction industry, tasks are allocated day wise. Because time base allocation is difficult monitor and time consuming. But some tasks can be completed within few hours according to the allocated work amount. Time is the most valuable resource in construction industry, by introducing micro level project planning to construction industry. Because of micro level project planning construction owners can speed up the construction process.
Introducing project planning feature using task time duration prediction and micro task planning and predefined construction job information. Project manager only have to enter few information and then they can generate project plan easily.

Project task can be started, stopped, terminated and rescheduled according to field environment. Field supervisors can efficiently manage tasks according to project plan by including notification features to alert task and labor availability, risks and completion. This feature avoids difficulty to manage micro level project management.

Task information gathered in monitoring module is used to predict task time duration in project planning level. Because of these features, managers and owners can get real time data, so that they can make immediate decision according to problems.

2. Literature Review

A. *Overall Equipment Effectiveness (OEE)*

According to [3], the OEE measure is the basic building block of a manufacturing improvement approach called Total Productive Maintenance (TPM). TPM is based on three interrelated concepts:

- Maximizing equipment effectiveness;
- Autonomous maintenance by operators; and
- Small group activities.

Therefore, OEE can be considered to combine the operation, maintenance and management of manufacturing equipment and resources [4]. The key criterion for success and long term effectiveness of TPM activities is the accuracy of the data [5]. OEE can identify which machine's performance is worst and indicates where to focus the TPM resources. The availability metrics can be directly applicable to building and construction machines based on the machines behavior [6]. In order to establish accurate availability rate, the six big losses must be measured accurately [7, 8, 9] since they consume resources without adding any value to the final product. Table 1 shows the Six Big Losses for the machines [6].

Table1: The Six Big Losses for the corrugators' machine

<table>
<tr><th>Equipment</th><th colspan="2">Big Six Losses</th><th>Computation of OEE</th></tr>
<tr><td rowspan="2">Downtime losses</td><td>Planned downtime</td><td>Breakdown</td><td rowspan="2">Availability efficiency = Actual operating time/Planned operating time</td></tr>
<tr><td>Unplanned downtime</td><td>Changeover</td></tr>
<tr><td>Speed losses</td><td colspan="2">Machine wear</td><td rowspan="3">Performance efficiency = Actual speed/ Theoretical speed</td></tr>
<tr><td></td><td colspan="2">Substandard material</td></tr>
<tr><td></td><td colspan="2">Operator Inefficiency</td></tr>
<tr><td>Quality losses</td><td colspan="2">Uncounted wastage</td><td rowspan="4">Quality efficiency = (Total number of product produced- number of scrapped)/ Total number of product produced</td></tr>
<tr><td></td><td colspan="2">Original defect</td></tr>
<tr><td></td><td colspan="2">Forklift defect</td></tr>
<tr><td></td><td colspan="2">Single face defect</td></tr>
<tr><td colspan="4">OEE = Availability efficiency x Performance efficiency x Quality efficiency</td></tr>
</table>

In a construction site, materials are very important to cost analysis of the project and also the planning the progress of the construction. These materials come in different forms. The materials can be liquids, solids or particles and their usage is different from material to material. Their application differs from material to material and also the way these materials handle, transport and store differs. Each material has unique and different quality. These unique and different qualities need to be tracked to find out the best material for a particular scenario. Wrong material type in wrong application can be a disaster.

The purpose of material prediction and rating system is to minimize the material wastage and manage material usage correctly and also to rate materials and their manufactures. Another material related problem is that inexperienced users who lack knowledge about these materials and these users may need assistance for selecting the product. Currently, in Sri Lanka, there is no such system. The need for a human expert is very important in this sort of situation. The

proposed system has an A.I. expert who can help to guide user to choose the product and this system considers the quality factors of a material and a rating score to guide the users.

B. Overall Labour Effectiveness (OLE)

Currently, there is no way to monitore the performance of individual workers in building and construction industry. Currently, in the industry, they pay workers by considering their working time. So, by monitoring the performance of workers we can get a clear idea about effectiveness of workers according to the task. To get details about the actual performance, there should be some special parameters to be taken for the calculations. After analyzing the workers, we suggest the best workers for individual tasks. To do this, we break down workers into three categories according to each task that each of the laborers is involved as skilled labor, semi-skilled and unskilled labor.

Firstly, we analyze the worker's performance then we rate them according to each task they have done. So, we maintain some standard matrixes for categorizing the worker.
Under skilled labor, if worker's analyzed rate is higher than standard matrix, we consider labourers as a skilled labor. In suggesting module, we analyze the rate of each worker and show the highest rated workers for each task and their availability.

Under Semi-Skilled labor, if worker's analyzed rate is equal to the standard matrix, we consider labourer as a Semi-Skilled labor. In suggesting module, we analyze the rate of each worker and show the highest rated workers and standard rate workers for each task and their availability.
Under the Unskilled labor, if worker's analyzed rate is lower than standard matrix, we consider the labourer as an unskilled for that particular task. So, according to this analysis, some workers may be unskilled for some tasks, but they may be skilled for some other task.
To rate a worker, we divide this whole module into the few sub modules.

Monitoring Performance:
Monitoring Attitude.
Monitoring Quality.
Monitoring Availability

C. Construction Task Duration Prediction

A man-hour is the amount of work performed by the average worker in one hour [13]. In the construction industry, man hour is the most practical way of measure task performance. The concept of man hours, also known as labor hours, measures the total number of hours put into a project or work performed in the course of a day by all employees combined. In the construction industry, labor hours can be compared against productivity to gain quantifiable insight into how much each employee contributes to the income gained from a specific job. This can help you to keep costs under control while providing strategic insight for managing employees' schedules, assignments and roles efficiently [14]. Therefore, prediction algorithms are designed based on man hour calculation. To predict few inputs are needed. Inputs are,

- Number of labors
- Work amount
- Previous task performance details

D. Micro Level Project Planning

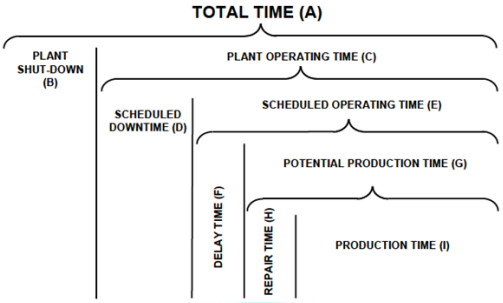
Construction planning is a fundamental and challenging activity in the management and execution of construction projects. It involves the choice of technology, the definition of work

tasks and the estimation of the required resources, durations for individual tasks and the identification of any interactions among the different work tasks [15]. In the current construction industry, project plan has been created by project manager. By introducing these features, managers can easily create a project plan. Every construction job information are pre-defined to collect performance details. When a project manager creates a plan, the manager has to select job. According to selected task, predicted task time duration returns.
In current times, Sri Lankan construction industry task work efficiency is too low. Therefore, lots of project have failed to complete on time. The main idea of introducing micro project planning is to increase task efficiency.

3. Methodology

Availability calculation of OEE can be directly applicable for calculate the availability in building and construction machines, but not performance and quality. Furthermore, availability can be categorized into following sections in order to get a clear understanding about the state of the machine (On/Off). Unlike the manufacturing industry, most of the time, building and construction machines are operated by machine operators. Therefore, a machine turn off will not always indicate the unavailability of the machine. Availability calculation algorithm generates the equipment availability, equipment utilization, process equipment utilization, potential equipment utilization and lost capacity based on table 2. Table 2 describes the way of measuring machine availability and different types of timing scenarios.

Table 2: Timing diagram



- Planned stop: The time during the shift where production is halted due to a planned event such as planned maintenance, cleaning, training, safety drills, meeting, R&D trial and stock check. Changeover The adjustment time between one batch ends to next batch run.
- Down time: The time where downtime can occur during the process.
- Actual speed: The length of paper roll to be produced per minute.
- Ideal speed: The target speed of corrugators to produce optimum output [9].

To acquire the availability details, it proposes a hardware based tracking device based on Arduino technology. GPS and vibration sensors can be used to obtain data from the machine. Vibration sensor is capable of generating signals when the machine is turned on even the machinery vehicle is not moving geographically. Moving vehicles can be analyzed the GPS sensor by analyzing the coordinates. Arduino introduces mercury type and ball type sensors in order to catch up the vibration. The Ball type sensor is the most applicable for this process.

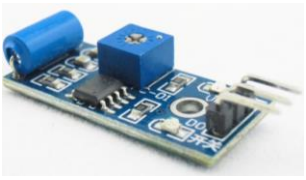


Figure 1: Vibration tilt switch

Vibration tilt switch is capable of returning a digital output the machinery vehicle is turned on. It should be fixed in a location where a vibration occurs. Some of the building and construction machines are not moving geographically when performing a task (Dragline). Therefore, this is mostly applicable for those types of machines.

Figure 2: Arduino based gyroscopic module

Arduino based gyroscopic module is used to extract availability and location information from moving machines.
By analyzing the vibration and movement factors, it is capable to generate the

- Equipment availability
- Equipment utilization
- Process equipment utilization
- Potential equipment utilization
- Lost capacity [10]

Performance is the second metric in order to consider when incomes to evaluate effectiveness. Performance evaluation of building and construction machines totally differs from the manufacturing industry. The research was based on four building and construction machine in order to measure the production. Production of the machine can be mapped as the performance.

- Hydraulic Excavator
- Backhoe
- Dragline
- Clamshell Bucket

Performance evaluation of hydraulic excavator was based on a custom made algorithm which inputs bucket volume, machine size, size of the dump bucket, bucket fill factor and the soil type. The above parameters are considered to calculate the production. Worked hours and planned hours are the inputs which are needed to map with the calculated production in order to calculate the performance. Production calculation is not straight forward.

Excavator Production (Lm^3/ hr) = C * S * V * B * E [11]

C: Cycles/h (Table 4.1)
S: Swing factor
V: Heaped bucket volume (Lm3)
B: Bucket fill factor
E: Job efficiency

There are separate algorithms based of the input values in order to calculate machine cycles, swing factors and bucket fill factors based on the following tables (Table 3, 4).

Table 3: Machine cycles and swing angles for excavators

	Machine Size					
	Small (Under 5 yd) ($3.8m^3$)		Medium (5-10 yd) ($3.8m^3$-$7.6\ m^3$)		Large (Over 10 yd) ($7.6\ m^3$)	
Material	Bottom dump	Front dump	Bottom Dump	Front Dump	Bottom Dump	Front Dump
Soft(sand, gravel, coal)	190	170	180	160	150	135
Average (common earth, soft clay, well-blasted rock)	170	150	160	145	145	130
Hard (tough clay, poorly blasted rock)	150	135	140	130	135	125
Adjustment for swing angle						
	Angle of Swing (deg)					
	45	60	75	90	120	180
Adjustment factor	1.16	1.10	1.05	1.00	0.94	0.83

Table 4: Bucket fill factors

Material	Bucket fill factor
Common earth, loam	0.80 - 1.10
Sand and gravel	0.90 - 1.00
Hard clay	0.65 - 0.95
Wet clay	0.50 - 0.90
Rock, well blasted	0.70 - 0.90
Rock, poorly blasted	0.40 - 0.70

Performance evaluation of dragline, it is more complex than hydraulic excavators. Dragline is a large excavator with a bucket pulled in by a wire cable. Dragline also contains a bucket where the maximum bucket size depends on the machine power, boom length and material weight. When it comes to production measurement, swing depth factors of the dragline and optimum depth cut are generated by separate algorithms where each output depends on the bucket size. The basic idea behind optimum depth cut is

% Optimum depth of cut=Actual depth of cut / Optimum depth of cut

Table 5: Ideal Dragline Output-Short Boom {BCY /hr (BCM/hr)} [11]

Type of Material	Bucket Size {yd³ (m³)}										
	0.75 (0.57)	1.0 (.75)	1¼ (.94)	1½ (1.13)	1¾ (1.32)	2 (1.53)	2½ (1.87)	3 (2.29)	3½ (2.62)	4 (3.06)	5 (3.82)
Light moist clay or loam	130 (99)	160 (122)	195 (149)	220 (168)	245 (187)	265 (203)	305 (233)	350 (268)	390 (298)	465 (356)	540 (413)
Sand and gravel	125 (96)	155 (119)	185 (141)	210 (161)	235 (180)	255 (195)	295 (226)	340 (260)	380 (291)	455 (348)	530 (405)
Common earth	104 (80)	135 (103)	165 (126)	190 (145)	210 (161)	230 (176)	265 (203)	305 (233)	340 (260)	375 (287)	445 (340)
Tough Clay	90 (69)	110 (84)	135 (103)	160 (122)	180 (138)	195 (149)	230 (176)	270 (206)	305 (233)	340 (260)	410 (313)
Wet sticky clay	55 (42)	75 (57)	95 (73)	110 (84)	130 (99)	145 (111)	175 (134)	210 (161)	240 (183)	270 (206)	330 (252)

A backhoe is a piece of excavating equipment or digger consisting of a digging bucket on the end of a two-part articulated arm. Backhoes are designed to excavate below the level of the machine. Production calculation of backhoes is similar to the calculation of hydraulic excavators, but swing depth factor is different based on the shovel and its properties (Table 6).

Table 6: Swing depth factors of for backhoes

Depth of cut (% of optimum)	Angle of swing (deg)					
	45	60	75	90	120	180
30	1.33	1.26	1.21	1.15	1.08	0.95
50	1.28	1.21	1.16	1.10	1.03	0.91
70	1.16	1.10	1.05	1.00	0.94	0.83
90	1.04	1.00	0.95	0.90	0.85	0.75

The clamshell bucket is a sophisticated articulating two-piece bucket mechanically hinged at the middle to form a claw-like appendage with an internal volume. It is attached by a hangar or bracket and uses ground engaging tool on its cutting edge to dig in a vertical direction.

When compared with other machines, there is a significant difference where production evaluation parameters of clamshells are only depends on the clamshell bucket.

Production = (VC / ECT) * HPC * BFF * (HW / HTW) [11]
VC: Volume per cycle
ECT: Estimated cycle time
HBC: Heaped bucket capacity
BFF: Bucket fill factor
HW: Hours worked
HTW: Hours to work

The maximum allowable load (bucket weight plus soil weight) on a clamshell is obtained from manufacturer's clamshell loading chart. The system generates the performance of the machine, by analyzing the production and mapping it with the cycle times.

System generates the performance of the machine, by analyzing the production and mapping it with the cycle times,

When it comes to evaluate the quality of a heavy machine, system uses a questionnaire which follows weighted scoring model. Weighted Scoring is a technique for putting a semblance of objectivity into a subjective process. Using a consistent list of criteria, weighted according to the importance or priority of the criteria to the organization, a comparison of similar "solutions" can be completed. If numerical values are assigned to the criteria priorities and the ability of the product to meet a specific criterion, a "weighted" value can be derived. By summing the weighted values, the product most closely meeting the criteria can be determined [12]. Questions are weighted based on a scoring model where one question can be more important than the other. There is an option to ignore questions if the question is not applicable. All the questions and weights are data driven, so the user can customize all based on the requirement. After acquiring the total score, it can be used as a percentage to measure the quality.

In the paint usage prediction algorithm one main parameter is the dry film thickness. Dry film thickness is probably the most critical measurement in the coatings industry because of its impact on the coating process, quality and cost [16]. DFT is the thickness of the paint after it's applied to a surface and dried out. Different paint types have different DFT values. This DFT value plays a main role when calculating the coverage ratios.

DFT = (WFT * % VBS)/100 [17]

DFT: Dry film thickness
WFT: Wet film thickness
VBS: Volume by solids

In the current industry, DFT and WFT values can be taken from gauges specifically created for this purpose. These gauges are fallen into four categories such as digital, mechanical, destructive and calibration standards. This equipment is not much popular in current construction industry in Sri Lanka. In that case some manufactures gives standard values for DFT and WFTs in their product specifications

Volume of the paint after its dried out is called volume solid. A paint contains vehicle, resin, pigments and additives and after the paint is dried out solid ingredients get left on the subtract. Pigments and resins are called the solid ingredients.

Volume solids= $\sum$ (VS x 100%)/ $\sum$ (VS) [18]
VS: volume solid ingredient in paint

Another factor to be considered by the prediction algorithm is the application method. Application method is the way how the paint is applied to a surface. There are three application methods such as brushes, rollers and sprayers. These sprayers are divided into another two categories called conventional sprayers and airless sprayers. These application methods causes different amount of paint losses during a paint job. Brushes and rollers have considerably the same amount of losses while airless spray guns and conventional spray guns do different percentages of losses. But, these values can be vary because of the environment condition. In an interior, there is no affect with environment factors like wind. But, in exteriors wind is a powerful factor that cause lots of paint losses especially if the application method is spray. Paint prediction algorithm considered this factor as well.

Next factor that the algorithm considered is the surface type. Paints can be applied to various surface conditions. But, the spreading rate will not be the same when applied to a rough surface and when applied to a smooth surface. In a rough surface, there is more friction and more surface area than expected because of inconsistent surface structures. So, that particular paint job of same size of area on a rough surface requires more paints than a same area size of a smooth surface. Surface after a paint can be a smooth surface. Basically, even if the first coat dealt with a rough surface, the second coat will be a smooth surface. Algorithm is aware of these sort of factors.

Algorithm takes area of the paint job, number of coats as basic parameters. These factors are normally must needed for a paint usage prediction. Finally, a custom made algorithm to make the prediction for the required number of liters.

Required liters= A/ (((VBS*10))/((DFT +AL + SL)))

A: Area

DFT: Dry film thickness
VBS: Volume by solids
AL: Application loss factor
SL: Surface loss factor

Considering all factors mentioned above and using the above mentioned equation, the paint prediction module calculated the predicted paint liters required for a particular task.

In concrete usage predictions, a must needed factor is the mixing ratio. These ratios can be changed from one concrete work to other and also these ratios can be changed according to the constructor's preferences and local standards. So, in that case, system uses international standard ratios for each construction work type. Ratios are pre-defined in the system so that according to the custom plan entered by the user algorithm sets the ratio for each and every concrete work that includes in the concrete task.

Table 7: Concrete mixing ratios [20]

Contruction	Materials Volume Ratio			Materials Required		
	Cement	Sand	Gravel	Cement *(sacks)*	Sand *(CY)*	Gravel *(CY)*
Normal static loads, no rebar, not exposed	1	3	6	4.2	0.5	0.95
Foundations and walls, normal static loads, exposed	1	2.5	5	5.6	0.45	0.9
Basement walls	1	2.5	4	5.6	0.5	0.8
Basement walls, waterproof	1	2.5	3.5	5.9	0.55	0.8
Floors, light duty, driveways, sidewalks	1	2.5	3			
Reinforced roads, walls, exposed	1	2	4			
High strength, floors, columns	1	1	2			

Ratios of material mixing are not enough for the algorithm to make the prediction. Another factor that would be required is the unit weights of the mixing materials. Unit weight also known as the specific weight is the weight of the material per a unit volume.

Unit weight = D * A [19]

D: density of the material
A: acceleration due to gravity

Theoretical unit weight of materials are measured with the unit kg/m3. There are standard unit weight values for construction materials which are used by the algorithm.

TABLE 8: Theoretical Unit Weights [21]

S.No	Material	Theoretical Weight in(KG/M³)	Approx Weight at Site in		Remarks
			Kg	Per	
1	Cement	1440	50	Bag	
2	Steel	7850	d²/162		d -dia in mm
3	Sand-				
	Dry	1600	50 to 55	farma	1 farma=1.25cft
	River	1840	57 to 63	farma	1 farma=1.25cft
4	Stone(basalt)	2850 to 2960	48 to 52	farma	metal 12mm to 20mm
5	Water	1000	1	liter	

Volume and area of the concrete work is another important and must needed factor for the concrete prediction algorithm. Main problem for the system is that the type of units these measurements are taken. According to the localization preferences, they use different units. These measurements can be taken as yards, feet or meters. But, the system needs a standard unit to do the calculations using the algorithm. Hence, the system uses meters as their preferred unit.

The concrete usage calculation uses dry mix method to give the prediction. In here, the system does the calculations for 1 cubic meter and then does the calculations for the required volume. But, when adding water, dry concrete volume decreases so that a correction for that value is made by adding 52% more volume to the dry concrete volume.

RMU= (DCV)/ ((CR+SR+AR))*RMR*MUW [22]
RMU: Required material usage
DVC: Corrected dry concrete volume
CR: Concrete ratio
SR: Sand ratio
AR: Aggregate ratio
RMR: Required material ratio
MUW: Required material unit weight

System outputs the required material quantities and costing. Calculating usage of material also includes adding rates for storing loss, transportation loss and handling loss to make the prediction more accurate.

Floor tile usage prediction algorithm is capable of predicting the optimized number of tiles for a particular flooring task and predicts the usage of grout if grout are used. When calculating and predicting the usage of floor tiles, area of the task and the size of the tile are the main factors that needed to be consider by the algorithm. There are different types of tiles available in present. There are tiles that need grout to fix the corrections and some tiles really don't want grouting or the amount of grouting is negligible. If grouting is required algorithm need the information regarding the thickness of the grout. With that information and the information regarding the area can help the algorithm to come up with the grout usage for the task.

Knowing the sizes of the tile can optimize the usage of the material as the algorithm can apply leftovers of a tile to a plan if such scenario occurs. By that algorithm can more accurate result of

tile quantity required for a particular task. Cost calculation is also done with this optimized result.

In the quality rating system each material type that's the system supports gets rated by the user feedback. This rating is done through a questionnaire that each question is focused on a quality factor of a particular material. Identified quality factor for each material must have a way to test with a simple observation. By these observations few conclusions are listed as answers with weighted values for each for user to pick up. This answer is taken as the percentage of positive feedback for that particular quality of the material. Other percentages is taken as negative feedback that will be used in the custom made algorithm.

There are six quality factors for each materials for the material rating purpose. Each material has a common quality factor that is the cost effectiveness. Rather than that other quality factors are unique to each material.

Identified paint quality factors are as follows,

- Durability.
- Covering ability.
- Cleaning easiness.
- Environment friendliness.
- Aesthetic.
- Cost.

Durability is the quality which determines how long a paint job can survive against various conditions. If paint can survive up to 5 years without fading and having fractures, that particular paint said to have a perfect durability quality. The area that can cover using a particular amount of paints with perfect finish is known as covering ability. Easiness of cleaning quality depends on how easy it to remove some sort of a stain from a paint surface. Not just that, it is considers the whether paint fades or completely removed in the cleaning process. If so, it said to have a bad cleaning support. Paints can be produced using chemical ingredients which are bad for environment as well as they can be produced using natural chemicals which are not a threat to the eco system. Bad unhealthy smell/breath soon after a paint job is an indicator that can identify this quality of a paint. Some paints are made for specific use in living rooms, dining rooms etc. These paints have a more aesthetic look rather than paints that are using for paint a storage room. If a paint looks nicer than other paint with a perfect finish, and also it has a good aesthetic score which determine the success of the paint job. Cost quality factor is just the price of the paint with respect to other products in the same range of types. Cement quality factors,

- Strength.
- Hardening speed.
- Plasticity.
- Easiness of workability.
- Moisture resistance.
- Cost.

The resistance against force and weight of a concrete work which was done by a particular cement and is the strength quality of the cement. Hardening speed is the time that a cement mixture is taken to be fully dried out. Quick setting is another name for this. These cements are very usable for quick constructions. If a structure or some form of concrete work can keep without changing its structure for some time is said to have good plasticity. If it is easy to change the shape of a concrete work without lots of resistance that cement have a good workability ratio. If concrete isn't leaking water through its base moisture resistance is surpluses by that

cement. Cost is simply the price of the one cement bag with respect to the other products within the same product range.

Floor tile quality factors,

- Slip resistance.
- Scratch resistance.
- Breaking strength.
- Edge tolerance.
- Heat/water absorption.
- Cost.

If a tile surface is not slippery, that tile has a good slip resistance. If a tile is slippery even without exposing to water have a bad slip resistance. If a surface can resist small scratches from day to day use its have a good scratch resistance ratio. Breaking strength denotes how much pressure that tile can take. If tiles can lay without too much variations on the surface, a tile which has good edge tolerance is going to have a nicely leveled floor. If a tile can easily vanish the heat or humidity on its surface have good heat/water absorption. Price with respect to similar ranges are the factor to determine the cost quality.

Rating output of the rating algorithm must be accurate and should deal with previous feedbacks as well. So that a variation of Wilson's score confidence interval is used in the algorithm. Rating algorithm need to balance the positive feedbacks with the uncertainty of scenarios with few feedbacks.

$$\frac{1}{1+\frac{1}{n}z^2}\left[\hat{p}+\frac{1}{2n}z^2 \pm z\sqrt{\frac{1}{n}\hat{p}\,(1-\hat{p})+\frac{1}{4n^2}z^2}\right]$$

Figure 3: Wilson's Confidence Interval [23]

$\hat{p}$: specific observation
n: total number of observations
z: (1-α/2) quartile of the standard normal distribution

In the customized algorithm $\hat{p}$ is taken as the positive feedback score and n is taken as the sum of positive and negative feedback.

There are some other factors that needed to make thing rating values more accurate. The person who has made the feedback can be a very experienced constructor who was working on the industry for many years or can be a house owner who doesn't have any experience about the construction industry. Therefore, that user level is tracked by an input to the system. According to this value feedbacks get prioritized. Another factor is the age of the task. There are some quality factors like, durability of a paint, strength of a concrete that are depends on the age. So that, the age of the task when the feedback was made is considered by the system to make the appropriate corrections to the feedback values.
Guidance system is a rule-based expert system that can output the product needed by the user after following a number of questions. A vast range of questions and rules are needed to be implemented to make an accurate result.

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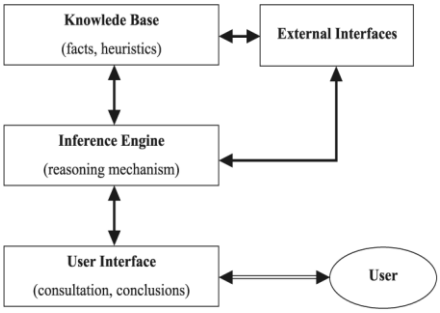


Figure 4: Expert System Structure [24]

Using OLE (Overall Labor Effectiveness) is a KPI (key performance indicator) that measures the utilization, performance and quality of the workforce and its impact on productivity.

In this module, the main focus is to identify the best workers based on their performance and suggest them for the best task which they can do effectively. It is based on a rating system where labourers can be rated according to their performance based on past task details. To rate the workers, there are some factors to consider. Based on Overall Labour Effectiveness (OLE) quality, performance and availability are the basic factors to measure the performance of a worker. But OLE cannot apply directly to this module because there are some more factors to consider when it comes to evaluating labourers in building and construction industry. When analyzing labourers based on a task, system prioritizes factors. As an example some task is dependent on another task. In this situation, availability is the most importance factor to be considered because if the previous attendance records of the labour who is engaged in the task is poor, dependent task workers cannot have a guarantee that the task will execute at the correct time. Likewise, according to the task priority of factors are going to change.

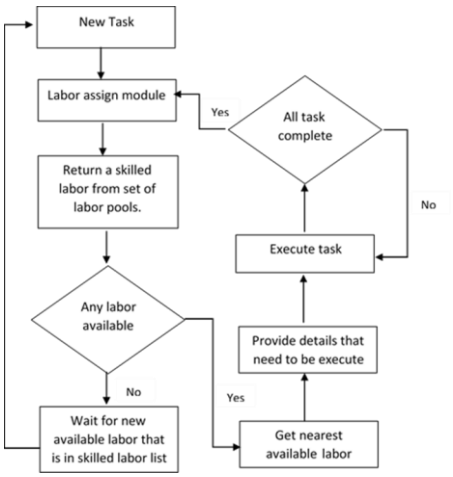


Figure 5: A task assigns for worker

To calculate the availability, system needs to access the previous attendance details. Attendance monitoring is done by using mobile based application, every labour has a unique QRCode. By scanning QRCode and by using mobile based application, system stores the check-in time and checkout time for each labour on each day. And also system have calendar to store holidays. And at the end of each month system calculates the availability rate value by considering overall attendance and holidays in each month.

When scanning the labours QRCode by using mobile application, it stores the details by connecting to the server remotely. It can be done via internet or locally.

After obtaining the rate value for each month system will provide an overall availability rate value for each labour by analyzing each month's rate value.

Performance calculation is done by considering the time taken to each task and workload on each day. When calculating the performance, if labour is not done with the daily workload or labours complete the daily workload spending more than standard time, system asks for a reason for the delay. When entering the reason, system provides some guide lines for the operator to enter the reason more accurately.

Quality Question Generated by using ontology. In ontology, questions are categorized according to the material which used in a task and also questions are weighted accordingly to their impotency.

After answering the question, system rates the task quality by analyzing the given answer and their weight.

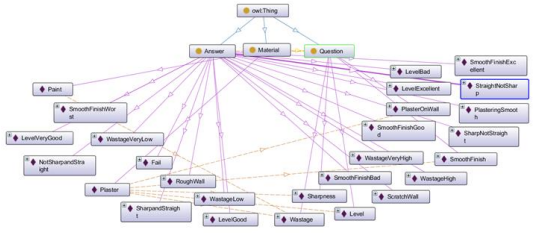


Figure 6: Quality Question Ontology

Attitude is also evaluated by given attitude question for each labour. These questions are also weighted by their impotency, after answering those questions, system generates a rate value for each labour by analyzing given answer and weight.

Finally, considering about all factors, workers can obtain one rate value according to each task. According to this value, worker can be categorized as:

- Skilled labor
- Semi-Skilled Labour
- Unskilled labor
- Skilled labor

According to the rate what they have for each task if it's going beyond the standard rate (two is a standard value) that labor consider as a Skilled labor and also system suggest only Skilled labor and Semi-Skilled labours for the task.

- Semi-Skilled

Under Semi-Skilled labor, if workers' given rate is equal to the standard matrix, we consider him/her as a Semi-Skilled labor. In suggesting module, we analyze the rate of each worker and show the highest rated workers and standard rate workers for each task and their availability.

- Unskilled

According to the rate and what they have for each task, if that value is less than the standard one, that worker is considered as an unskilled labour for that specific task, so according to that, skilled labors can also be unskilled for some tasks and unskilled labors can also be skilled for some tasks.

Here, this module helps obtain more wage for skilled labors according to the task. So this module helps for identifying the best workers among the workers and ways to increase their performance and also for unskilled labor.

Construction job details are categorized according to their measure unit and ordered according to completion order. These job details are used to create project plan and store previous task completion details. Construction job details can only manage by project manager.

Once work construction job have been defined, the relationships among the activities can be specified. Precedence relations between activities signify that the activities must take place in a particular sequence. Numerous natural sequences exist for construction activities due to requirements for structural integrity, regulations, and other technical requirements [27]. After adding construction job, precedence of job can be defined. These relations are use when suggesting the next available task to supervisors.

Construction jobs can have more than one technique to do it. This information also needed to predict durations. Therefore, calculates task efficiency according to following techniques.
Also, construction job efficiency change according to environment. Project manager have to add separate environment effect records. In current industry, records about raining weather conditions only. Introducing to collect task efficiency data according to the weather conditions. It also considers the hot and raining weather climates. But these effect change one task to another task. When adding the construction job project manager has to add effecting climates to job considering the technology use to do it.

Developing the construction plan is a critical task in the management of construction, even if the plan is not written or otherwise formally recorded. In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project [27]. By including project planning tool with prediction features support managers to do planning easily. This tool is developed to create project Gantt chart easily. In the current industry, MS Project is mostly used to create project plan. When using MS Project, project manager has to enter everything manually. Because of pre-defined construction job only have to select correct job and proceed. After that project manager has to allocate starting date, number of labors and techniques to do the task. Project plan generate as Gantt chart.

In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control. Some projects are primarily divided into expense categories with associated costs. In these cases, construction planning is cost or expense oriented. Within the categories of expenditure, a distinction is made between costs incurred directly in the

performance of an activity and indirectly for the accomplishment of the project. For example, borrowing expenses for project financing and overhead items are commonly treated as indirect costs. For other projects, scheduling of work activities over time is critical and is emphasized in the planning process. In this case, the planner insures that the proper precedence among activities is maintained and that efficient scheduling of the available resources prevails. Traditional scheduling procedures emphasize the maintenance of task precedence (resulting in critical path scheduling procedures) or efficient use of resources over time (resulting in job shop scheduling procedures). Finally, the most complex projects require consideration of both cost and scheduling over time, so that planning, monitoring and record keeping must consider both dimensions. In these cases, the integration of schedule and budget information is a major concern [27].

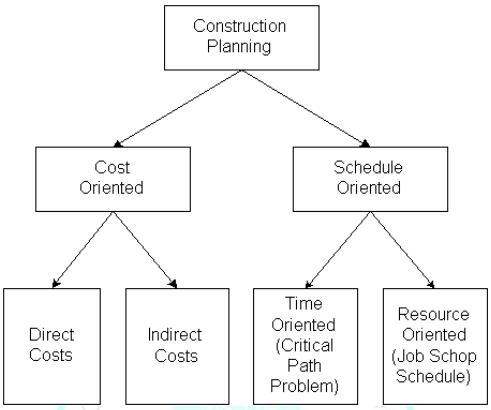


Figure 7: Alternative Emphases in Construction Planning

Main target is to avoid project failures. Therefor use schedule oriented planning to plan projects. Use micro level project planning to increase efficiency of project. Therefore, time oriented approach use for project planning. Construction project are large scale and more time consuming.

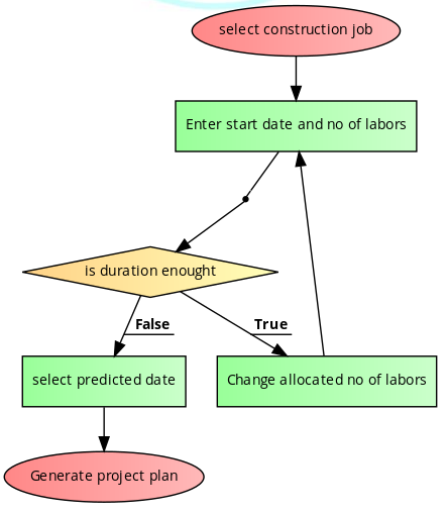
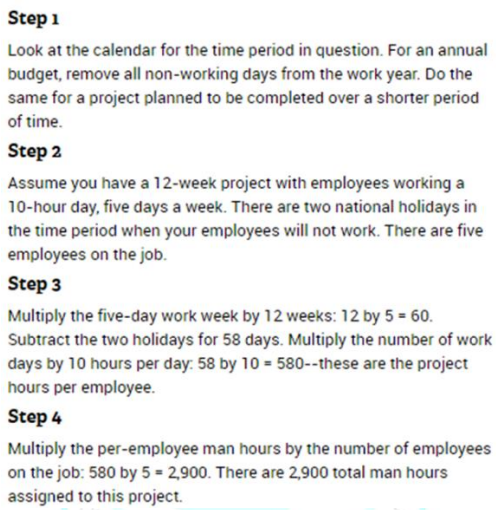


Figure 8: Project plan creation

Best way to manage construction task is to divide them into sub part and manage them. Tasks of project master plan can divide into sub-task. Because work break down task labors can assign to task efficiently by Labor Management module. Then, sub-tasks are monitored by the supervisor. Supervisors can start, stop, terminate, reschedule sub-task according to environment. Supervisors have record climate changes. According to the updating climate automatically predict task duration and if can't complete sub-task within allocated duration system alert to responsible supervisors to take actions.

A man-hour is the amount of work performed by the average labourer in one hour. It is used in written "estimates" for estimation of the total amount of uninterrupted labor required to perform a task [25].


Step 1

Look at the calendar for the time period in question. For an annual budget, remove all non-working days from the work year. Do the same for a project planned to be completed over a shorter period of time.

Step 2

Assume you have a 12-week project with employees working a 10-hour day, five days a week. There are two national holidays in the time period when your employees will not work. There are five employees on the job.

Step 3

Multiply the five-day work week by 12 weeks: 12 by 5 = 60. Subtract the two holidays for 58 days. Multiply the number of work days by 10 hours per day: 58 by 10 = 580--these are the project hours per employee.

Step 4

Multiply the per-employee man hours by the number of employees on the job: 580 by 5 = 2,900. There are 2,900 total man hours assigned to this project.

Figure 9: Example man hour calculation

Prediction is done analyzing previous task completion details and considering the current climate of the construction area. When predicting in project planning phase, climate don't consider.
First, get the average efficiency of the task by calculating average duration of completed tasks before. After getting average efficiency value of the task, it is multiply by no of labors and work amount of the task. Result of the multiplication is the predicted time duration of the task.

$$\text{Average Task Efficiency} = \sum \frac{\text{Time taken to compete task}}{\text{(Number of labors * Work amount)}}$$

Figure 10: Average Task Efficiency

After starting the project automatically predict the time duration to identify risk. In this stage get construction field climate as an additional input.

Conclusion

Based on the test results from the algorithms, it was proven that all the algorithms successfully resulted most efficient values in order to have a better effectiveness on resources. Heavy machinery related effectiveness measuring algorithm generates the effectiveness values in order to get a clear understanding about the machine usage. Material usage production algorithms

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returned the possibilities in order to guide to use materials with a minimum wastage when performing a task. Labour effectiveness measurement and ratings algorithms returned the effectiveness measurements of the labourers. By combining all the three types of resources, the project planning and scheduling related algorithms were able to predict the project duration real time.

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References

i. 'Calculations and Formulas Guide for Paints and Coatings.' (n.d.) *Excalibur Paint*. [Online] Available at: http://www.excaliburpaint.com. Accessed 28 August 2016.

ii. 'Concrete Mixtures.' (n.d.) [Online] *The Engineering ToolBox*. Available at: http://www.engineeringtoolbox.com/concrete-sand-cement-gravel-mixtures-d_1547.html. Accessed 28th August 2016.

iii. 'Construction Planning.' (n.d.) [Online] Available at: http://pmbook.ce.cmu.edu/09_Construction_Planning.html. Accessed: February 17th 2016.

iv. 'Expert System.' (n.d.) [Online]*Expertsystem101*. Available at: http://expertsystem101.weebly.com. Accessed 28th August 2016.

v. 'How do you estimate the quantity of cement sand aggregate in 1 meter cube of concrete?' (n.d.) [Online] *Quora*. Available at: https://www.quora.com/How-do-you-estimate-the-quantity-of-cement-sand-aggregate-in-1-metre-cube-of-concrete. Accessed 28th August 2016.

vi. 'How to Estimate Man-Hour Productivity in Construction.' (n.d.) [Online] Available at: http://smallbusiness.chron.com/estimate-manhour-productivity-construction-80878.html. Accessed: February 17th 2016.

vii. 'How to Estimate Man-Hour Productivity in Construction.' [Online]. Available at: http://smallbusiness.chron.com/estimate-manhour-productivity-construction-80878.html. Accessed: February 17, 2016.

viii. 'Personal PM Tutor.' [Online] *American Eagle Group*. Available at: http://terms.ameagle.com/2011/01/david.html. Accessed 28th August 2016.

ix. 'Unit Weight of Materials Used at Construction Site.' (n.d.) [Online] *Civil Engineering Portal*. Available at: http://www.engineeringcivil.com/unit-weight-of-materials-used-at-construction-site.html. Accessed 28th August 2016.

x. 'What is a Coating Thickness Gauge?' (n.d.) *Elcometer*. [Online] Available: http://www.elcometer.com/en/coating-inspection/dry-film-thickness/calibration-standards Accessed 28 August 2016.

xi. Atun, A. (2010). CE431. 'Construction Management.' (Class Lecture, Topic). CE 431, Department of Civil Engineering, Near East University, North Cyprus.

xii. Dal. B., Tugwell. P. & Greatbanks, R. (2000). 'Overall equipment effectiveness as a measure of operational improvement: a practical analysis', *International Journal*

xiii. Kotze, D. (1993). 'Consistency, accuracy lead to maximum OEE benefits', *TPM Newsletter*, 4(2).

xiv. Ljungberg. O. (1998). 'Measurement of overall equipment effectiveness as a basis for TPM activities', *International Journal of Operations and Production Management*, 18(5), pp. 495-507.

xv. Nakajima. S. (1988). *Introduction to Total Productive Maintenance (TPM)*. Cambridge, MA: Productivity Press.

xvi. Nakajima. S. (1989). *TPM Development Program*. Cambridge, MA: Productivity Press.

xvii. Ngadiman, Y., Hussin, B. & Abdul Majid, I. (2011). 'Exploring overall equipment efficiency model of laboratory capital equipment in Malaysian Public Universities.' International Conference on Industrial Engineering and Operations Management, 22-24 Jan 2011, Kuala Lumpur, Malaysia. 11566

xviii. Pask, A. "Yes, you need to be able to define "a part" in your process. This might be a repetitive movement (e.g. a machine cycle), or a depth progress. The important thing is that during "production" you make multiple "parts" and that the time between these parts should be consistent if the process is running well." Personal e-mail communication. (Jeb. 18, 2016).

xix. *Production Equipment Availability, A Measurement Gyuideline* (2011) 4.

xx. Ramlan, R., Ngadiman, Y., Omar S. S. & Yassin A. M. (2015). 'Quantification of Machine Performance Through Overall Equipment Effectiveness.' *International Symposium on Technology Management and Emerging Technologies, Langkawi, Kedah, 2015*. p. 2.

xxi. *VA: The Association for Manufacturing Technology*.

xxii. Vorne Industries, Inc. (n.d.) 'What Is OEE (Overall Equipment Effectiveness)?' [Online] Available at: http://www.oee.com/. Accessed 26th August 2016.

xxiii. Wikipedia (2016) 'Man-hour.' [Online]. *Wikipedia*. Available: https://en.wikipedia.org/wiki/Man-hour. Accessed February 17, 2016.

xxiv. Wikipedia (2016) 'Man-hour.' [Online] *Wikipedia*. Available at: https://en.wikipedia.org/wiki/Man-hour. Accessed: February 17th, 2016.

xxv. Wikipedia (n.d.) 'Binomial proportion confidence interval.' [Online] *Wikipedia*. Available at: https://en.wikipedia.org/wiki/Binomial_proportion_confidence_interval. Accessed 28th August 2016.

xxvi. Wikipedia (n.d.) 'Specific weight.'[Online] *Wikipedia*. Available at: https://en.wikipedia.org/wiki/Specific_weight. Accessed 28th August 2016.

xxvii. Wikipedia (n.d.) 'Volume Solids.' [Online] *Wikipedia*. Available at: https://en.wikipedia.org//wiki/Volume_solid. Accessed 28th August 2016.