# An empirical study of the impact of knowledge management strategies on waste and rework reduction in construction projects during post-contract award stage in UAE

دراسة تطبيقية لأثر استراتيجيات إدارة المعرفة على النفايات
وتقليل اعادة العمل في المشاريع الانشائية خلال مرحلة ما بعد
منح العقود في دولة الإمارات العربية المتحدة

**by**


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# Abstract

The UAE is considered to be one of the major contributors to construction waste in the world. The nation has been confronting the challenge of implementing sustainability in its construction sector in order to reduce its environmental footprint. One of the main causes of waste in construction is the presence of rework during the construction stage of different projects. It was identified that the sources of rework can be generated from each of the parties involved in the construction process. The major causes of rework in UAE comes down to the eagerness of developers to deliver high end buildings in a challenging duration from the project inception to its conclusion. One of the other causes of rework is the lack of awareness of the magnitude of rework impact on the project's environmental foot print. This extends to the lack of awareness of the methodologies required to tackle such problem. A survey as part of this research was conducted to identify the magnitude of rework experienced by different construction professionals. Furthermore, causes of rework were identified from the literature and were evaluated in the survey to confirm their applicability to the construction sector in UAE.

The research also incorporates a case study from UAE to understand some of the existing strategies to reduce rework as well as discuss possibilities of improving some of these strategies increasing their impact. Furthermore, the outcomes of the case study combined with further literature review to identify strategies to reduce rework that are applicable to the construction sector in UAE actionable by contractors were identified. These strategies were then presented to construction professionals from different backgrounds who are working within a building contracting entity to verify the solutions positive effect on reducing rework.

Rework is a serious epidemic that have been impacting the construction sector all over the world. The main reason for that is the absence of reporting on its occurrence which makes building the business case against it very difficult. The requirement to reduce rework can have significant sustainable benefits to the construction sector in UAE.

# الخلاصة

دولة الامارات المتحدة تعد من أكبر المساهمين بالنفايات الناتجة عن اعمال الانشاء في العالم. حيث تواجه الدولة تحديا في تحقيق الاستدامة في قطاع الانشاءات لأجل تقليل التأثير البيئي الصادر من هذا القطاع. أحد اهم أسباب النفايات الناتجة عن اعمال الانشاءات هي إعادة تنفيذ الاعمال في فترة التنفيذ الانشائي لمختلف المشاريع. مصادر أسباب إعادة تنفيذ الاعمال قد تعود الى كل من الأطراف المساهمة في الاعمال الانشائية. الأسباب الرئيسية التي تؤدي الى إعادة تنفيذ الإعمال هي رغبة المطورين الملحة لتنفيذ مشاريع ذات جودة عالية خلال فترة زمنية ضيقة من بداية فكرة المشروع الى نهايته. سبب اخرمن أسباب إعادة تنفيذ الاعمال هو قلة المعرفة بعمق التأثير البيئي الذي يخلفه إعادة تنفيذ الاعمال لأي مشروع. يكون هذا السبب عادة مصاحبا لقلة المعرفة بالفعاليات التي تؤدي الى تقليل إعادة تنفيذ الاعمال. تم تنفيذ دراسة إستبيانية من خلال هذا البحث لمعرفة كمية إعادة تنفيذ الاعمال التي يقوم بها العاملين بالأنشطة الانشائية من مختلف الخلفيات. بالإضافة الى ذلك، تم تحديد بعض من أسباب إعادة تنفيذ الاعمال من البحوث الاكاديمية وتم ادراجها في الدراسة الإستبيانية لتحديد مدى مطابقة هذه الأسباب لقطاع الانشاءات في الامارات العربية المتحدة.

يقوم هذا البحث أيضا بتناول حالة بناء من الامارات العربية المتحدة لفهم بعض الطرق المستخدمة حاليا لتقليل إعادة تنفيذ الاعمال من قبل المقاولين بالإضافة الى مناقشة احتمالية تطوير بعض هذه الطرق للزيادة من فعاليتها في تقليل إعادة تنفيذ الاعمال. هذه الطرق بالإضافة الى طرق أخرى تم التعرف عليها من بحوث اكاديمية قد جمعت لتشكيل مجموعة من الحلول لتقليل إعادة تنفيذ الاعمال حيث تكون قابلة للتطبيق في قطاع الأنشاء الاماراتي. تم عرض هذه الحلول على بعض العاملين في قطاع الإنشاءات ذوي خلفيات مختلفة ولكن يعملون ضمن شركة مقاولات إنشائية للتأكد من الأثر الإيجابي الناتج من هذه الحلول على تقليل إعادة تنفيذ الاعمال.

إعادة تنفيذ الاعمال هو حالة جدية كانت ولازالت تؤثر سلبيا على قطاعات الانشاء حول العالم. ويعود السبب الرئيسي لهذا الوضع الى انعدام توثيق حالات إعادة تنفيذ الاعمال في المشاريع الانشائية مما يؤدي الى صعوبة توضيح أسباب تطبيق أي من الحلول لهذه المشكلة. متطلبات تقليل إعادة تنفيذ الاعمال تعود الى الفائدة الكبيرة المرتقبة في جعل قطاع الانشاءات أكثر استدامة.

# Table of Contents

# List of Tables

# List of Figures

# Chapter 1: Introduction

## 1.1. Introduction:

Throughout the past twenty years, the concern for the symptoms of climate change and the signs of damaged environment have become evident due to various activities; one of the top influencing activities is considered to be the ones within the building and construction sector (Zhao, et al., 2016). The same perception is shared by Ranaweera and Crawford (2010). Researchers such as Yang and Zou (2014), Yang et al. (2016), Okodi-Iyah (2012), Morel, et al. (2001), Coelho and de Brito (2012),Wu, et al. (2014) and Broun and Menzies (2011) illustrate that around 40-50 % of reported global energy consumption is by the aforementioned sector. Furthermore, this sector contributes to 40% of the total landfill disposed waste, 40% of greenhouse emissions and 40%-60% of global raw material consumption.

The altitude of these figures is directly correlated to the market development and especially the building and construction sector development. This sector has witnessed significant boost in many countries. An example would be the sector's development in UAE where by the end of the first quarter of 2010; the GDP from construction in UAE reached up to 23 billion USD (Okodi-Iyah, 2012). Putting this figure in context, the US had achieved around 540 billion USD of GDP from construction in the same period (IECONOMICS, 2017). Should a GDP Density comparison take place between the two countries in terms of construction development considering the fact that the US is around one hundred and seventeen times the size of the UAE; the US achieved over fifty four thousand USD per square kilometer whereas the UAE achieved over two hundred and seventy five thousand USD per square kilometer; that's over five times what the US was achieving which reflects the intensity and the momentum construction has in UAE (Trading Economics, 2017).

Furthermore, and due to the high level of construction saturation the UAE is enjoying, the construction sector always strives for efficiency in its production (Touran, 2010). Yet such efficiency has grown to be highly fragmented and disconnected as each sub-process strives to improve its own efficiency regardless of other sub-processes constraints or requirements. Resulting in frequent disruption to the construction process of a project in general. Such climate which is characterized as vastly growing yet fragmented would push any party within the construction process to try to accelerate the execution of their scope even when there is missing information.

This acceleration usually forces the execution to proceed on “half-cooked” information provided by the consultants which generally causes rework down the road (Bossink & Brouwers, 1996). Delayed information can also increase the possibility for materials to be damaged due to storage on site awaiting information (Al-Hajj & Hamani, 2011). These sorts of scenarios have become the norm in UAE (Kerr, et al., 2013) as more and more competitors fight to win projects which need to be delivered with extreme speed. However, this usually compromises quality and leads to rework and waste. Furthermore, this would impact negatively on both the building’s environmental performance during and after construction duration.

Design related risks are usually among the risks that are pushed on to the contractor which leads to what most of the consultants in the region call “the coordination process”. This process is known as the attempt of the contractor to coordinate the design while the project is being erected. Such scenario usually takes place when a consultant issues a portion of the contract documents communicating a performance criteria rather than an actual element that needs to be installed. Basically, providing contract documents for a project that can’t be followed literally for construction but require further interpretation and development to be both workable and constructible.

An example is where the consultant would provide the design for the HVAC package for a certain project yet notes within the contract documents that the air flow within a duct should be verified by the contractor or should meet a certain value. This forces the contractor to evaluate the design and in some instances, resize certain ducts to achieve the required air flow. In parallel, the structure is progressing allowing for the duct size as per the contract documents since the modification in the duct size wasn’t picked up earlier. The result is a wrongly sized opening within the structure which cannot accommodate the revised duct size. Therefore, leading to further rework in an attempt to divert the said duct to another zone where it can be accommodated or the initiation of a structural study to allow the contractor to resize an existing opening within a structural element. Such decisions grow less and less in flexibility as change become more difficult and expensive as the project is being constructed.

Furthermore, the construction industry by its nature is considered a wasteful process and this has to do with the different activities that take place on a construction site such as rework which is identified as a common problem in the construction sector with extents reaching up to 3-23% of total project value (Love, et al., 2004).
Therefore, the focus of this research is to highlight how information flow and management have caused rework to occur in construction projects. Moreover, the research would study how rework occurrence can be reduced if information is managed appropriately in a context of fast paced delivery. The research will attempt to devise an environment where accuracy and timely availability of information is ensured despite increased modern projects complexity and increased number of stakeholders. Furthermore, it will illustrate how information can be navigated between its creators and users. Such environment should allow the creation of an information body or a common data environment that anticipates, allows and documents information creation, modification and flow.

## 1.2. Aims:

The aim of this research is to come up with a set of knowledge-based strategies that can be implemented in a post contract award stage by the contractor. These strategies would help reduce rework and waste caused by poor knowledge management.

## 1.3. Objectives:

The outcomes of this research are expected to achieve the following:

- Identify how knowledge management can impact rework and waste occurrence in construction highlighting the significance of rework and waste on the environmental footprint of a construction project.
- Validate the above-mentioned causes and identify applicability and relevance to UAE construction practices.

- Assess current strategies of knowledge management that are implemented by contractors in a post contract award stage which are being utilized to reduce or eliminate rework and waste.
- Propose and validate strategies with the contractor's scope in a post contract award stage to reduce the impact of poor knowledge management on rework and waste creation.

# Chapter 2: Literature review

## 2.1. Rework: Definition and impact:

Rework is defined by Construction Industry Development Agency as ‘‘doing something at least one extra time due to non-conformance to requirements’’ (Ison, 1995). Another definition for rework is the redo and recovery process of making the constructed subject satisfy the original construction goal (Ashford, 1992). Rework is also defined as the process or event caused by deviations, faults, unqualified quality problems, or quality accidents (Love, 2002). The latter definition seems to be the most relevant even though major repairs are considered as rework by some researchers since it is interpreted as the process of restoring an item to a condition that is acceptable or to its original condition (Ashford, 1992). Yet the author believes that there should be a differentiation between what is being considered as rework during construction and what really falls within the area of renovation. The latter should include items that have been operating to an acceptable level for a certain period of time and at a certain point they stop functioning and they need to be replaced due to normal wear. However, should the items malfunction due to improper installation or overload for example then it should be considered as rework. This is since the original installation (physical) and/or the original design (virtual) of these items were not done correctly in the first place.

Rework can happen in two forms; virtual and physical. The virtual rework can be defined as “redoing a task of design or updating information due to modified base information or requirements”. An example of that is modifying a ducting layout to accommodate revised structural layouts or the addition of a block wall to an architectural general arrangement layout. Literature shows that design change can happen at least two times to get the information sorted out correctly (Cooper, 1993). Furthermore, virtual rework due to changes in design or miss-coordination accounts for around 50-79% for the total cost of rework in a project as highlighted by Burati, et al (1992) and Love (2002) (1999). The Physical rework can be defined as “revisiting an already executed physical item for modification or removal”. An example of physical rework is the demolition of an existing wall that was recently erected and the erection of a new wall due to change in design requirements. It is worth noting that there is not much attention paid to the physical rework aspect when it's an addition work. Adding a new partition to a room that was recently erected for example. The reason for the same is not clear. However, the author argues that the same should be considered as physical rework and that it's defiantly a virtual rework. This is due to the fact that this change has to do with either additional design requirement or updated base information. Furthermore, it should be considered as physical rework since it may have an impact on works which are already done other than the partitions creating rework for other trades (flooring, ceilings and paint, etc.). Furthermore, Physical rework can also happen due to merely execution problems, which has to do with the quality of the execution and delivery of the final product.

The two types of rework have a certain level of interdependency since virtual rework may lead to physical rework, an example would be if a designer relocated a wall on a drawing (virtual rework) and that wall is already built as per the original design, the builder will have to demolish the existing wall and erect the new one (physical rework).

The other way of how the rework types interdepend is when there is a backflow in information. Such backflow usually originates from wrongful execution. This in a way would pressure the virtual state of the work to change to allow for the physical state of the work to remain unchanged even if it was executed incorrectly. An example would be when a designer would relocate a wall on a drawing to match an existing wall on site which was recently erected incorrectly or in response to site restraints. The second type of interdependence seems to have more efficiency to it as it limits the physical change of materials and attempts to conserve it. However, it might induce a domino effect on other trades which may be impacted by the change, an example would be if the wall which was built incorrectly is supposed to host a cabinet which was fabricated based on the dimensions of the wall in the design documents, this will result in the cabinet being no longer fit for purpose and a possible rework (potentially both virtual and physical) may be required as a result of not following the design drawings on site.

Furthermore, the later discussed scenario can happen virtually only. An example would be when ELV (Extra Low Voltage) cables are virtually rerouted to avoid clashing with drainage pipes (which are sloped to fall) during coordination process, the drainage system is governed by gravitational forces and a start (drain point) and an end point (riser) whereas the ELV cables are known to be very flexible due to their relatively small diameter. The result is a virtual system being modified to accommodate the requirements of another virtual system. This exercise is usually common as it is more efficient to address issues virtually rather than physically eliminating the element of physical waste.

There seems to be a complex cycle that might take place once rework is involved in the project delivery cycle as illustrated in Figure 1; this has resulted in substantial problems in construction projects. The literature doesn't seem to attempt to quantify rework in terms of physical material quantity yet it measures it in regards to cost overruns. This may include cost associated with other than material loss such as labor force cost, waste removal disposal cost and / or penalty cost due to delay induced by the rework process.

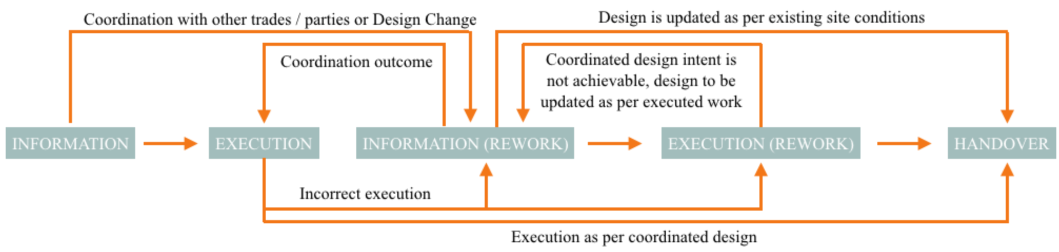


*Figure 1 :Design to handover cycle (Author)*

The other aspect of rework impact is what comes after the rework process; basically, the aftermath of the rework which extends to the pressure construction teams endure. This is mainly due to added (or repeated) activities which probably weren't calculated in terms of man power allocation or project time frame planning. Literature shows that in some cases and due to rework, the duration of a project can span to around 245% of the initial time estimate of a project (Aiyetan & Das, 2015) and with an average of 22% in some countries (Love & Edwards, 2004). Such pressure will probably induce a faster rate of work for the balance tasks and activities which would encourage working out of sequence and/or without obtaining the right approval (proceeding without approved shop drawings, material submittals, method statements, etc.). This will leave less room for errors to be spotted which may lead again to rework as a result as highlighted by Love (2004), Aiyetan & Das (2015) and Pate-Cornel (1990). Furthermore, rework would incur cost overruns on the project which would again encourage the utilization of cheap materials and commissioning poor workmanship to execute the work which would result in rework again. (Aiyetan & Das, 2015).

The main negative aspects of rework are that they can happen in a lot of different forms as what will be discussed in the coming sections of this chapter, making it very difficult for managers to accurately grasp its existence & extent in a project and react accordingly. Furthermore, and due to the nature of construction activities in being successive (certain activities can't commence unless the preceding activities are concluded), the full impact of rework is very difficult to establish as the impact can extend all the way up to the last activity on site especially if the activity infused with rework is considered to be a critical aspect of the project plan.

Other than the effort required to execute the rework scope when it occurs and the cost and time impacts that results from this phenomena in a project, rework extend its impact from the project context to the environment in general since the main outcomes of rework are either over consumption and/or more waste. This plays a significant role in increasing the environmental footprint of the project during its construction period along with the total embodied energy of the building which has an impact on the environment. Furthermore, improper construction due to project pressure can reduce the efficiency of the operation of the building impacting further its environmental footprint throughout its life cycle.

## 2.2. Rework causes:

Rework can have a significant impact on the construction process of a project; this impact may not be limited to redoing a certain task because it doesn't satisfy the established requirements but can extend to applying pressure on the project's time line and its financial plan. This can happen by creating new tasks to be done which has to do with the rectification of an existing item which wasn't planned in the first place and wasn't allowed for commercially (Love, et al., 2004). The result of this process will again pressure work to be done in faster pace to catch up the delayed timeline or program using cheaper means to limit the financial losses inducing more rework. This can create a vicious closed cycle that can drain the project's resources since rework will cause further rework unless managed properly and ultimately increasing the environmental foot print of the project and its embodied energy.

Rework causes vary in origin as much as they vary in impact and they are usually caused by the lack of the application of quality control measures and procedures whether during design or during construction (Palaneeswaran, 2006). Furthermore, design and construction firms have usually maintained no record of the errors that took place while carrying out their tasks thereby limiting their knowledge of the mechanisms that causes or prevents errors and rework (Han, et al., 2013).

As explained in the first section of this chapter, rework can happen in two forms; either virtual or physical.  These two types of rework share a common factor which is the fact that there should be an extent (if not all) of the work that is already been done where in redoing it what is called rework takes place. Unless it's a physical work executed incorrectly deviating from the design which needs to be rectified to match the design, most cases of rework are the result of design information of some sort or discipline. This information would form the base of the next design task or physical work. Therefore, it is safe to state that rework despite why or how it is induced (unless it is being done due to physical nonconformance to the intended design), it will not take place without revised information (refer Figure 1). One would argue that rework induced by program pressure as an example of rework not induced by design rework, such statement is correct as program pressure may lead to poor workmanship which would render a physical element not in accordance with the design. Therefore, rework will be induced by the physical conditions of the element where it deviates from the design intent or detailing.

Mendelsohn (1997) suggests that design changes are the main influencers which would induce change and ultimately rework. The same was confirmed by the Building Research Establishment (1981). Love, et al (2002), Aiyetan & Das (2015) and Yap, et al (2016) all suggested dividing the factors inducing design changes based on their origin as the following (Refer Figure 2):

- Internal factors: factors controlled or induced by one or more of the project participants or parties. An example of internal factors would be poor design documentation produced by the Consultant.
- External factors: Factors which are not controlled or induced by any of the project participants or parties. An example of external factors would be a change in municipal code requirements.

Internal factors can be divided into four sub-categories based on their origin and as the following (Mohamad, et al., 2012):

- Design related factors
- Contractor related factors
- Client related factors
- Project related factors

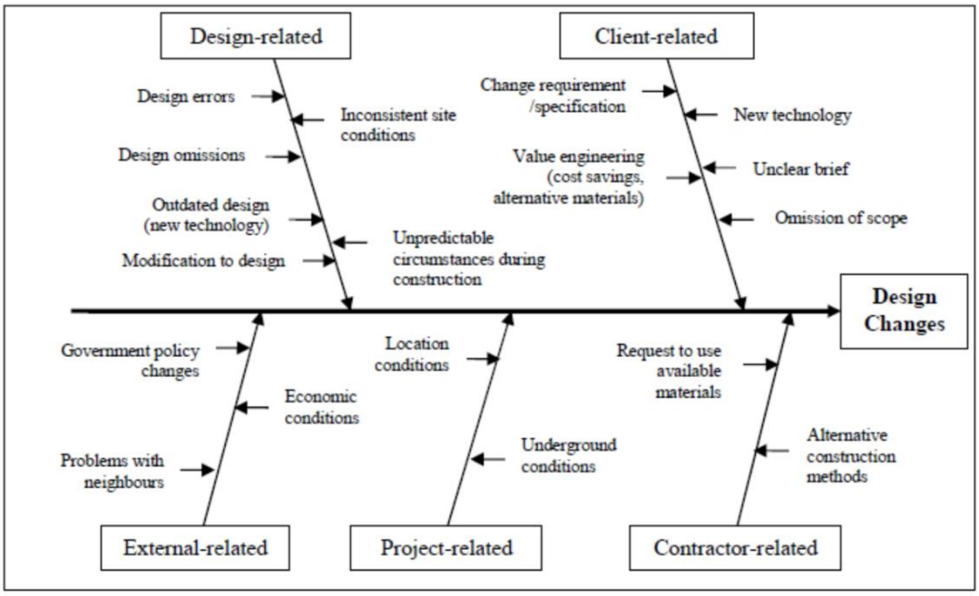


*Figure 2: Generic cause-and-effect diagram of design changes (Yap, et al., 2016)*

It needs to be noted that the literature indicated the first point as Design related factors rather than Consultant related factors which the researcher agrees with. This is since in UAE and as part of the region’s practice, upon the commencement of a project, the contractor assembles a team of engineers from different disciplines who would carry on the final detailing of these disciplines and prepare the final drawings used for construction. This is due to the fact that the drawings received from the consultants are usually not developed or coordinated enough to be used directly in construction without undergoing certain processing. Therefore, the design term reflects both the part of the consultant and the scope of the technical team within the contractor. One would argue that this can fall under the “Contractor related factors” as it is the contractor’s technical team’s scope. However, it is considered by the author as under design to separate the factors involving the physical construction rework on site from the matters involving the design in general.

Furthermore, there are design changes which are caused by more than one group of factors, most of the times in a sequential manner; an example would be when the Contractor requests to change the detailing of a certain element to enhance the installation process on site. This may be followed by the Consultant’s instruction to add further adjustments to the same element to re-align it with the design intent maintaining the constructability of the element as requested by the Contractor (Yap, et al., 2016). Therefore, the change was created by both the contractor and the consultant.

### 2.2.1.Internal factors of design changes

#### 2.2.1.1. Design related factors:

As per the National Economic Development office (1987), the main factors that had influence on the quality of the construction works were factored back to design due to poor coordination and unclear information. This extends to poor design documentations produced by the design consultants of the project which literature shows that it can cause up to 5% of the project value in rework (Burroughs, 1993). Furthermore, rework causes factored back to design consultants in general ranking up to 20% of the value of the consultant’s fee (Gardiner, 1994). Even though in some cases, the consultants would claim that their design documents and detailing are fit for purpose (Love, et al., 2004). Literature doesn’t seem to cover the design induced rework factors which are caused by the Contractor’s technical team whom the author argues have a good share of the rework causes especially in construction contexts such as the UAE's. This is because they act as the final pit where all information is gathered and processed to issue what is known as shop drawing for construction purposes, reason being is that this team have access to a larger data base of information in comparison to the Consultant. This is due to the fact that they have a direct link if not in control of the materials which to be procured/fabricated despite the disadvantage of taking design decisions while the project is being constructed.

The causes behind design factored design change can be summarized in the following:

- Poor communication between the client and the consultant during the design briefing and between the lead consultant and the sub-consultants during the design stage as highlighted by Yap, et al (2016) and Love, et al (2004).

This may be the result of inexperienced staff employed by either party, fast track design program/timeline, limited interface between the designers and client and poor management and documentation skills. Furthermore, this can be the result of poor management from the lead consultant. This is due to following a sequential design strategy where a sub-consultant would have to finish his scope for the following sub-consultant to start with unspecific occasions of up-stream information; this usually results in the leading information package (usually the architectural package) being one revision ahead of other disciplines if not more. Which suggests the existence of discrepancies during the time of submission (such as during issuing documents for tender and for construction).

- Lack of relevant or sufficient expertise within the assigned design/technical teams (Wong, et al., 2001).

Addressing this issue has a possibility of holding true to the benefit of the project at first glance, yet the author believes that this raises a question of how competition will be cultivated. This is since no new players are allowed to enter into the market if the most basic requirement for taking on a certain scope is to have done it before. Such approach continues to drive up the price tag for consultancy and contracting services rather unnecessarily in the author's opinion. Whereas that "additional"

expenditure may better be spent on improving the quality of the delivered project. However, the main drawback is the risk that a client would have to go with a "younger than advised" consultant or contractor; this may give the client the chance to reduce or eliminate cheap material usage in the project since the construction budget would increase due to appointing consultants with lower fees. However, this can be turned in as an overall cost saving from a project management perspective reducing significantly the benefit intended.
In addition to the above, there is no argument that teams with experience have more potential in avoiding mistakes and rework. Therefore, careful selection of designing, detailing and executing teams is deemed significantly important to limit waste in a project especially due to errors and rework.

- Design is set to be executed with certain systems and construction techniques that are outdated (Al-Momani, 2000).

This can be due to fact that the consultant is not appointing a specialist to execute the design of a certain scope and/or is relying on using existing information applied in previous projects. This will result in not updating the intended design and installation technique with the latest utilized methodologies. Furthermore, this can extend to execution preference from the contractor for logical ease of production or installation which is usually not prioritized by the consultant if the project delivery method is design-bid-build. An example would be the following design of façade fixation detail to structural concrete; Figure 3 shows a side accessed cast-in channel where the curtain wall bracket is bolted.

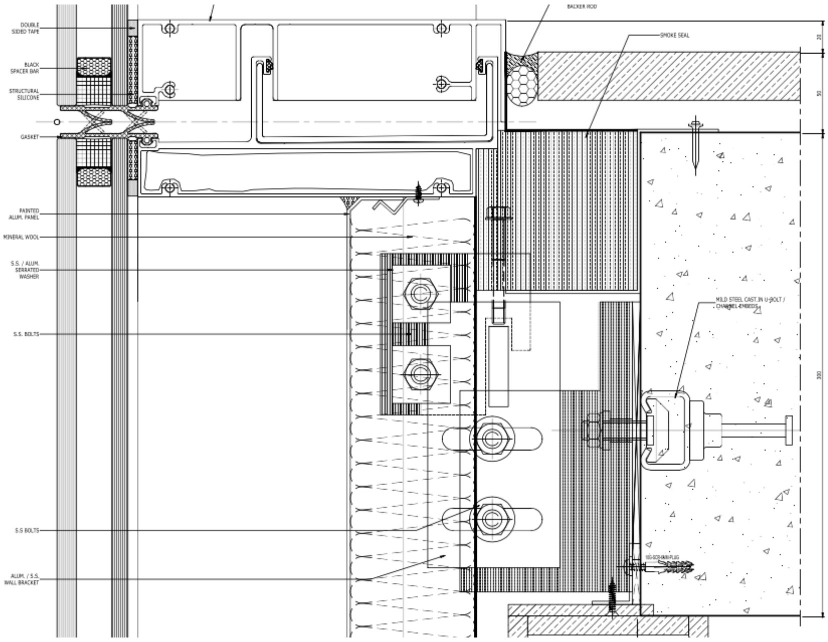

*Figure 3: Facade interface detail with structural slab - consultant's detail (Author)*

This detail requires employing a monorail crane with a suspended work platform to install the bracket which gets fixed on the cast-in channel. This would pose an accessibility issue to the façade contractor which would result in an elongation of the duration of the installation process. Therefore, the façade contractor proposed an alternative detail illustrated in Figure 4 where the cast-in channel is accessible from on top of the structural slab to bolt the façade brackets.

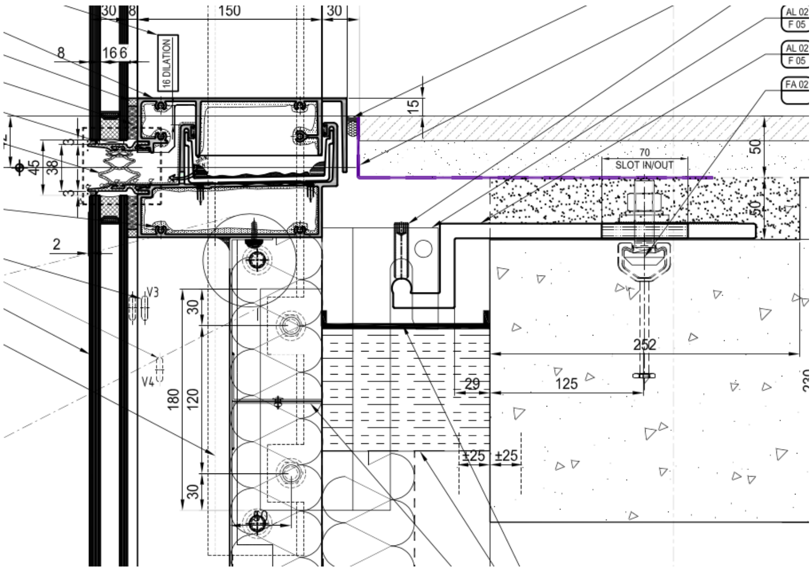


*Figure 4: Facade interface detail with structural slab - contractor's detail*

The implications of this change not only impacted the façade detail of the project and the structural calculations of the brackets but also impacted the structural detailing of the concrete slab. This is since the top mounted brackets require a recess in the concrete slab in order to avoid clashing with the floor finishes. This design change (rework) was done since the consultant didn't consider the contractor's obvious and logical preference. Furthermore, the consultant has failed to keep himself up-to-date with latest installation technologies. Moreover, he has failed to fulfil his duty in this particular case in specifying what is best for the project and its stakeholders. The above example is from the author's experience from a real project in Dubai, UAE.

- Unanticipated design load and design changes due to errors, missing information and unforeseen site conditions as highlighted by Yap, et al (2016), Mohamad, et al. (2012) and Al-Momani (2000).

This can happen due to improper planning of resources, weak understanding of the project and it requirements, bad or incomplete information within the contract documentation, incorrect execution of the design scope and lack of experience. This would result potentially in delayed design information delivery to the construction team. Such scenarios would force them in most cases to work out of planned sequence increasing the probability of rework occurrence.

- Competitive bidding from the consultants as highlighted by Rounce (1998) and Love, et al (2004).

This may result in low design fee that may not possess sufficient contingency for unanticipated design load or unforeseen site conditions.

- Time boxing; which is basically setting a fixed duration for each design task regardless of its status being completed or not (Rounce, 1998).

This may result in delivering information for construction that is not completed or at least haven't been checked for quality.

- Misalignment between information readiness and construction activities.

This may happen due to unavailability of information from the consultant or the subcontractors or fluctuations in the durations of the approval cycles for information submitted by the contractor. This may result in unanticipated information delivery to site forcing construction to commence in some cases despite unavailability of sufficient or approved information due to construction program pressure.

- Suppliers or subcontractor not on-board with the construction due to unconcluded commercial issues.

This may result in blocking or delaying information flow between the project parties impacting information delivery time.

All of these factors can be measured by how good the final product of the design is; that final product is the drawing that the builder or the fabricator will use during construction or fabrication. The quality of that drawing is basically a result of a set of steps or procedures such as conformance to design intent, detailing being approved by relevant parties, conformance to specifications, drawing undergone QA/QC checks, coordination with other relevant disciplines in a timely manner, constructability reviews, scheduled delivery, etc. Such scenarios when achieved can guarantee an accurate construction or fabrication drawing establishing the foundation for accurate and precise construction.

#### 2.2.1.2. Contractor related factors:

Contractor related factors of design changes can happen due to a number of factors. Preference to use locally available materials to have better control over material flow to the construction site along with or due to cost savings benefits is one of these factors. Other factors are the change in construction methodology to conserve time and/or money and rectification of construction nonconformance and errors. This is where the contractor may ask to change the design intent to match the executed physical element in order to avoid physical rework (Mohamad, et al., 2012).

Further factors include insufficient use of information technology as highlighted by Aiyetan & Das (2015) and Love & Edwards (2004). This also extends to insufficient skill levels including within the technical team appointed by the contractor (Fayek, et al., 2003). An example of the last two points would be missing a clash that happens between two services in a room, the usual solution requires reducing the inverted level of one of the services to resolve the clash which would ultimately lead to reducing the room's ceiling height inducing design change.

#### 2.2.1.3. Client related factors:

Literature by Mohamad, et al (2012), Alnuaimi, et al (2010), Hwang, et al (2014) and Thyssen, et al (2010) indicate that client related factors causing design changes have a significant impact on the rework rate in a project. Further literature by Aiyetan & Das (2015) and Arain & Low (2006) summarizes the major client related factors to design changes as per the following:

- Changes of design induced by client (including intent, material and specifications).

This can happen due to updated project requirements to maintain project relevance to the market or to meet updated requirements or preferences for prospective owners/clients, responding to unanticipated financial situation in client side forcing a measure of value engineering to take place to reduce the project's cost (Hwang, et al., 2014), unforeseen site conditions or constraints (Yap, et al., 2016), nonconformance of the contract documents with the design intent which may be due to poor briefing or poor communication between the client and the consultant (Yap, et al., 2016), design development done by the contractor due to insufficient information provided by the consultant, this will result in the contractor implementing the cheapest option which would conform to building regulations should this be under his scope without consideration to client preference, this is since this part was missing from the contract documents and tendering stage.

Furthermore, change in design can happen due to poor design service provided by the consultant. This will include failure of highlighting nonconformance to standard practices or relevant codes in the design brief to the client or providing inaccurate information for budgeting and pricing (Palaneeswaran, 2006). These changes will result in a delay or at least a disruption in the preparation of shop drawings by the contractor. This is due to the fact that shop drawings would by halted awaiting the conclusion of the revised intent required by the client and potentially the resolution of the financial issues concerning this change between the project's parties.

Moreover, this would create a possible domino effect impacting other trades due to the change in one of the trades. An example would be relocating a bed space in a bedroom which will not only impact the ID layout of the room but will extend to relocating the electrical containment and sockets for example which is required for the lamps on the bed side tables.

- Inadequacy in the preparation and the communication of the design brief and project objectives.

This can happen due to improper allocation of time and funding for briefing (Hwang, et al., 2014), poor experience within the client's team and / or the consultant's team (Aiyetan & Das, 2015), limited design budget (Rounce, 1998), limited interface opportunities between the client and the consultant and the assignment of consultants to only supervise the execution who had nothing to do with the design. The impact of this cause can be evident when a local developer (client) appoints an international consultant with little or no physical presence in the area where the project is to be built. Such a condition will limit interfacing opportunities between the client and the consultant to digital means or occasional visits at project's milestones from the consultant. More importantly, such scenarios will force the international consultant to appoint a local consultant as the "official" consultant of the project. This is due the requirements of establishing a presence in the area by the international consultant which may not be feasible in terms of time and or cost; therefore, allowing the local consultant to act as what is known as "The Architect of Record (AoR)". The duty of the AoR would be to interface with the local authorities and obtain relevant approvals and permits for the project. Furthermore, the AoR in most cases will be awarded the construction supervision scope of the project reviewing the contractor's submittals against the contract documents and overseeing the construction processes.

This scenario can probably increase the gap between the design intent envisioned by the client, the design intent understood by the international consultant and the design intent understood by the local consultant and the contractor through the contract documents. Such situation can cause a possible misalignment between the client's design intent and what's being constructed on site which would force the client to initiate a design change.

- Financial problems faced by the client (Aiyetan & Das, 2015).

The reasons for client financial problems can vary from bad economic climate to poor management or slow sales. This can result in an initiation of value engineering processes in an attempt to reduce the project's cost by changing the designer, the contractor and/or the contract documents. Other results of financial issues such as delayed payment can lead to a project's halt which will potentially induce design rework in the author's opinion. This is since a designer will have to reacquaint or study the current design in its current stage to resume working on a paused project. Especially if the team involved with the project previously has been changed when the project resumed.

- Client's indecisiveness.

Yap, et al (2016) discusses client's indecisiveness and how it impacts rework in a project. This can be due to poor handover of design brief within the client's organization (from design management department to construction management department), absence of clarity in the design brief since not all prospect stakeholders are on-board yet with the project, an example would be the fact that clients usually delay the appointment of a facility manager for a project in order to reduce costs associated with his employment (salary, benefits, etc). The absence of such team member can have a significant impact on the final product due to his awareness of prospect tenants' requirements and post construction building operation and maintenance, such requirements may not be picked up by the designers. This will result in potential design change instructions from the client to make the final product more appealing to prospective tenants and/or easier to maintain (Aiyetan & Das, 2015).

Furthermore, the indecisiveness of the client towards elements detailed by the contractor in accordance with the contract documents which are not in accordance with the client's design intent, a design change in this case once requested will have a cost and time impact bared by the client. Furthermore, causes such as unfamiliarity with the design and construction codes and standard practices, lack of experience and disputes between the client and other project parties can complicate the decision-making process (Aiyetan & Das, 2015).

Lastly, unavailability of decision making personnel on the client's side, this can result in consultants pushing ahead with their design scope in the absence or delay of feedback from the client. This is because there would be a cost impact for prolonged design period (working beyond the "time box" of a certain design task). Therefore, resulting in a possible deviation between the produced documents by the consultants and the design intent provided by the client that wasn't present during the execution period of a certain design task, ultimately pushing the client to issue design change. This links back to the role of a facilities manager as discussed earlier (Aiyetan & Das, 2015).

- Client's insistent nature.

This factor can be divided into two aspects, the first aspect is relating to the pressure imposed by the client on the consultant to commence the tender for a project even before the completion of the design and coordination processes. Which would result in an inaccurate tender and lead to conflicts between the client, the consultant and the contractor. Furthermore, this will cause site activates to commence without the availability of full information to the contractor which can result in rework. This is since the base information is still being developed by the consultant and may be updated in the future (Newton, et al., 2014).

It is worth noting that project managers often attempt to expedite the commencement of the construction of a project while the design is being carried out. This approach to project delivery is known as "fast track project delivery" which intentionally allows construction to commence despite the absence of a full information from the consultant potentially causing rework during construction (Waldron, 2006), refer to Figure 5.

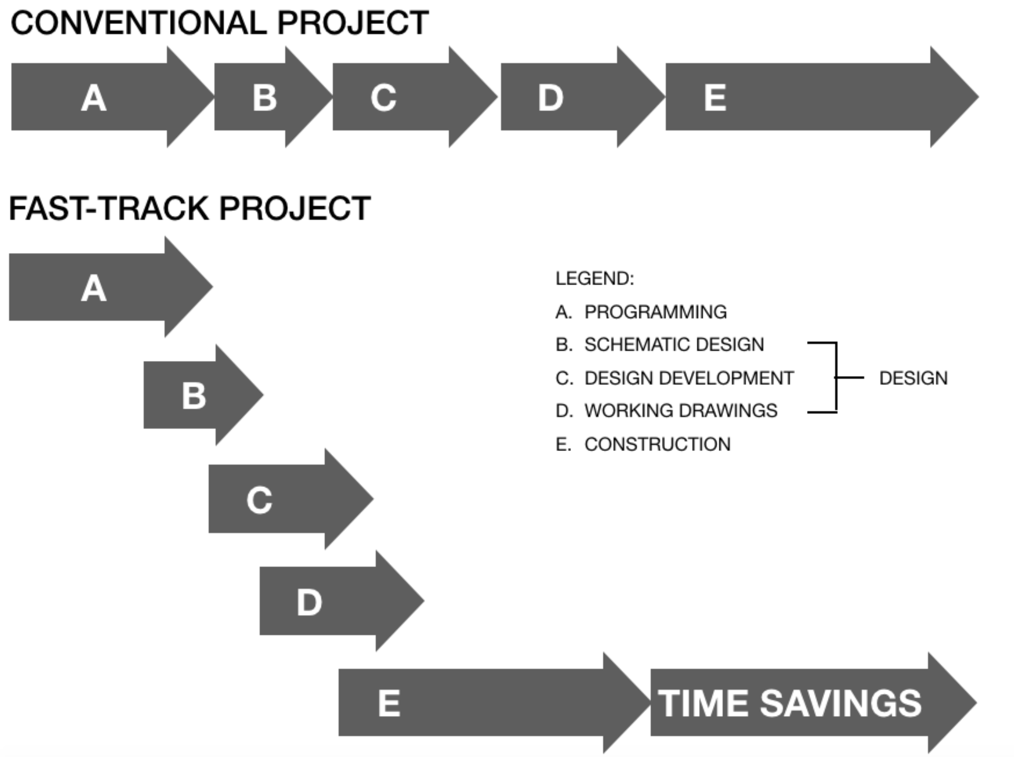


*Figure 5: Comaprision between conventional project and fast-track project delievery (Alcabes, 1973)*

The second aspect by itself may not cause rework directly. However, in the event of wrongly executed elements on site causing “up-stream” information where it is more efficient to adapt the change virtually in the design rather than redoing the work physically on site, client insistent nature can force the contractor to rectify the error on site. It’s to be noted that both scenarios of adopting the error in the design and repairing the error on site will cause rework (virtual and physical respectively). However, the extent of the latter can be far more wasteful. The downside of adopting contractor’s errors can have a reversed impact as it may encourage the contractor to adopt less strict quality measures causing more errors and rework.

- Poor or insufficient funds allocated to site investigations.

This can result in inaccurate contract documentations as they might not match the site conditions. This could cause possible physical rework during site enabling works, waterproofing works and/or foundations works for example along with the abortive and additional engineering works to accommodate the site constraints during construction. Furthermore, this can extend to the negligence of temporary site constraints or conditions by the consultants assuming the consideration of the same as the responsibility of the contractor. An example of that is illustrated in Figure 6 below.

*Figure 6 : Inclined struts supporting shoring wall in a construction site(Author)*

The inclined struts shown in the above figure were required by the piling contractor to support the shoring wall during excavation works. This is due to the fact that the implementation of an anchor tieback system was not feasible due to the proximity of the project to a water body making the soil looser due to the higher content of water. The excavations were required to conclude the piling works as the project had two basement floors.

The complication arose as in order for the struts to be removed, the retaining wall of the basements along with the raft and basement one slab needed to be casted to withstand the load that was being absorbed by the struts from the shoring. This required a certain construction sequence that forced the casting of the walls and the slabs around the struts to enable the removal of the struts. The removal of the struts thereafter was followed by capping of the voids which were occupied by the struts in slabs and walls. Therefore, forcing significant engineering works from the contractor since this issue was not captured in the contract documents and imposing delays on the project squeezing the delivery schedule due to late start.

- Limited client involvement in the project.

This will result in poor briefing to the consultant leading to poor communication of design intent within the contract documents. Causing potential over or under designing of the project that would either force the client to implement value engineering exercises and/or issue design changes respectively. It should be noted that frequent client involvement may not mean less rework as it would indicate more frequent interferences and change orders from the client side which if it didn't impose physical rework; it would defiantly impose virtual rework (Love, et al., 2004). Clients' active involvement in the beginning of a project can have a positive impact on the project success as the client would ensure that his brief has been followed, however his role may start to have a negative impact on the project process. This is due to the fact that change is being induced as the project moves toward the finish line which will have a negative impact on the work progress.

- Low design service / contract documentation preparation payment.

This will result in poor design quality which means that mistakes will be discovered during construction and would lead to project delays and rework. This factor will also result in having poor quality of contract documents including project budgeting and pricing. Therefore, forcing value-engineering actions from the client which may have to induce rework. Moreover, this factor can lead to misalignment between the client's design intent and the contract documents, undiscovered or unanticipated design scope, delayed information delivery and the employment of aggressive time boxing strategies to limit the duration of each design task despite its status are other results of this factor which all will contribute directly or indirectly to rework (Rounce, 1998).

Furthermore, consultant's attempt to reduce their fees by eliminating allowances for rework on design documentations. This will result in the lack of implementation of the client's comments on the design documents. Moreover, this will limit the interaction between different sub-consultants among each other and with the lead consultant as each has a limited number of revisions to achieve as per the budget. Impacting negatively on the quality of the provided documents as part of the contract (Love, et al., 2004). It is worth noting that the client himself usually play a significant role in inflecting this problem to a project (Aiyetan & Das, 2015).

#### 2.2.1.4. Project related factors:

The main factor of this category that causes design changes and rework is site constraints (Aiyetan & Das, 2015).the impact of the same can be reduced or eliminated if proper site investigations are carried out as all of the discovered obstacles can be factored into the design and the planning of the project. Such obstacles can include project location (Love, et al., 2002), accessibility and underground conditions as discussed by Mohamad, et al (2012), Sambasivan & Yau (2007) and Hsieh, et al (2004).

It needs to be noted that project's complexity level is not a project related design change factor but a design related design change factor. As should this complexity be well captured by the consultant within the contract documents and well absorbed by the contractor's team then the complexity issue is resolved. Which is why one of the common aspects for low rework rate for both simple and complex projects is the thorough understanding of its design intent among all parties.

### 2.2.2. External factors of design changes:

External factors of design changes have to do with the elements that are not created or controlled by the project's shareholders. These elements include influencers of change that are within the context that surrounds the project or where the project is placed rather than from within the project itself. This section will discuss the different elements that can remotely induce design changes within a construction project.

Local codes and regulations play a significant role in shaping the design of a project (Love, et al., 2002). Therefore, any change in its requirements during design or construction will impact how the project is performing in terms of progress (Hsieh, et al., 2004).

Code requirements changes in UAE is forgiving in most cases. This is since any change in requirements is studied properly to ensure that it is not disruptive to ongoing construction. Therefore, changes in municipal requirements are usually dedicated to projects that have not obtained a building permit. This means the consultants still have a chance in implementing these changes without a significant impact on construction as it didn’t start yet (building permit is a prerequisite for construction to start). However, the impacted segment can increase depending on the criticality of the changes. An example would be the changes instructed by Dubai Municipality within circular 215 issued in April 2016. The circular addressed the application of fire rated materials in buildings and in cladding applications. The issuance of this circular caused a bit of a stir in the construction sector in UAE especially with regards to applications of façade systems which were halted in numerous projects in Dubai. Works commenced after contractors and consultants fully understood the circular’s requirements and demonstrated compliance for the same.

Furthermore, these requirements include guidelines that regulate whatever interface a project has with the services provided by local authorities or local service providers. The agreement on the interface between the building and the services provided by local authorities or service providers is usually established via an engineering submission containing all relevant information. This submission is then reviewed by the local authorities or service providers and may undergo certain revisions and discussions which can have an impact on the building design. This impact is constituted as an externally induced design change. An example would be obtaining an approval for a building’s electrical substation space (where the Ring Main Units (RMU) are installed and then connected to transformers) from Dubai Electricity and Water Authority (DEWA). DEWA usually supplies the equipment therefore they govern the design of the substation room to match the requirements of the available units. These requirements include the datum level of the substation room, accessibility, relationship to adjacent spaces, provisions (openings) in structural elements, etc. Mismatch between the provisioned space provided by the consultants and DEWA requirements happens in some cases. This forces the consultants to adopt DEWA requirements in their design which would create an externally induced design change.

It needs to be noted that the aforementioned approval is done in separation from obtaining the building permit. Therefore, contractors could erect an entire building with the building permit obtained from Dubai Municipality and without obtaining an approval on the electrical substation from DEWA. This poses significant risk as the built substation space may not correspond to DEWA's requirements. This may then force the consultant to issue a site instruction to the contractor to execute physical changes to align with DEWA's requirements. However, such scenario shouldn't be considered as an externally induced design change but internal design change instead. This is since the consultant didn't obtain timely approval from DEWA on the substation design. Furthermore, the consultant has allowed construction to take place without clear information from the service provider.

External factors also include the environmental, economic and the political climate of the project's area (Aiyetan, et al., 2011). This may extend to availability and price fluctuations of resources such as materials and construction tools in the local markets as it is linked directly to how well a project is progressing (Alaghbari, et al., 2007). The major impact of these elements has to do with construction program pressure where work has to stop and resume later on without impacting the end delivery date. Environmental conditions can impact construction program pressure as site activities can't take place in extremely windy condition due to safety requirements for example. An example of economic conditions includes economic rescissions were cash flow gets disrupted causing the work to halt on site. Political elements include any political activity within the region where the project is placed that creates instability and lack of security in a way that obstructs construction process.

Most if not all of these factors can't be influenced or controlled let alone anticipated therefore projects remain in a reactive condition when it comes to external factors.

### 2.2.3. Factors contributing to physical execution that is nonconforming to design or quality standards:

Further to the exploration of design change causes in the previous sub-sections of this chapter and the illustration of how they can lead to rework. This sub-section will explore the reasons why the design intent cultivated by the contractor's technical team is not always followed on site. Furthermore, this sub-section will explore why would the contractor in some instances ends up producing physical elements that are not in accordance with the design intent and / or project quality standards. Factors affecting the same are as the following:

- Limited access to latest information by the construction teams.

This can be the result of having multiple contact points between the technical teams and the construction teams where information may not be forwarded to all relevant parties (Aiyetan & Das, 2015). This is especially evident when a technical department of a subcontractor issues information solely to its construction team while working in isolation from other technical teams. This extends to sharing information over limited access platforms such as private emails or hard-copy information which prevents other parties from knowing that the there is an updated or revised design (Eastman, et al., 2008). Furthermore, failure of the technical team in notifying the construction team in the event of revising a design allowing the construction team to progress with outdated information can lead to rework (Tribelsky & Sacks, 2011).

- Lack of experienced and skilled labor force (Low & Goh, 1994).

This can be the result of squeezed budget where the project can't afford experienced labors or due to increased work pressure due to delays in project program (Arashpour, et al., 2013), forcing the contractor to assign labors to construction tasks who don't possess sufficient or relevant experience (Aiyetan & Das, 2015). This will lead to poor and inacceptable quality where work will have to be redone due to lack of understanding of the relevant construction methodologies and standard practices, misinterpretation of drawings and specifications, lack of coordination and planning capabilities and inability to spot problems or mistakes within the provided design (Simpeh, 2012).

- Project budget pressure.

This can be the result of poor financial planning (Arashpour, et al., 2013), delay in project delivery, fluctuations in construction materials and equipment prices (Gündüz, et al., 2013), inaccurate pricing and tendering and tough payment conditions from the client (Aiyetan & Das, 2015). This will result in possible acceleration in work program to cut duration costs which will force labor forces to work faster increasing the room for error (Touran, 2010), this extends to the procurement and the utilization of poor construction materials and equipment which may result in bad quality work, employment of low experience staff or labor force, reduction of the size of the staff and or the labor force base size influence less to do more (Enshassi, et al., 2017).

- Poor quality of information.

Aiyetan & Das (2015) and Arashpour, et al (2013) both suggest that this can be the result of lack of experience, absence or lack of quality checks, absence or lack of constructability reviews, lack of planning for design activities, insufficient time to prepare information for construction, incomplete or delayed coordination information and poor information presentation. This can result in incorrect construction or delay in construction activities due to the ambiguity of the provided information or the requirement for clarifications, additional information or revisions to the provided information for construction.

- Lack of discipline (working out of sequence).

This can be the result of lack of experience in construction (Aiyetan & Das, 2015), lack of coordination between different activities and parties (Serpell, 1999), lack of planning, lack of implementation of disciplinary measures in the events of violations (managerial weakness), availability of resources, materials and equipment and availability of information (Gündüz, et al., 2013). This would result in delay in construction works, rework for activities which started out of sequence due mainly to provide access or to establish interface with following activities. An example of the above would be the interface between internal ceiling and the façade with reference to Figure 7.

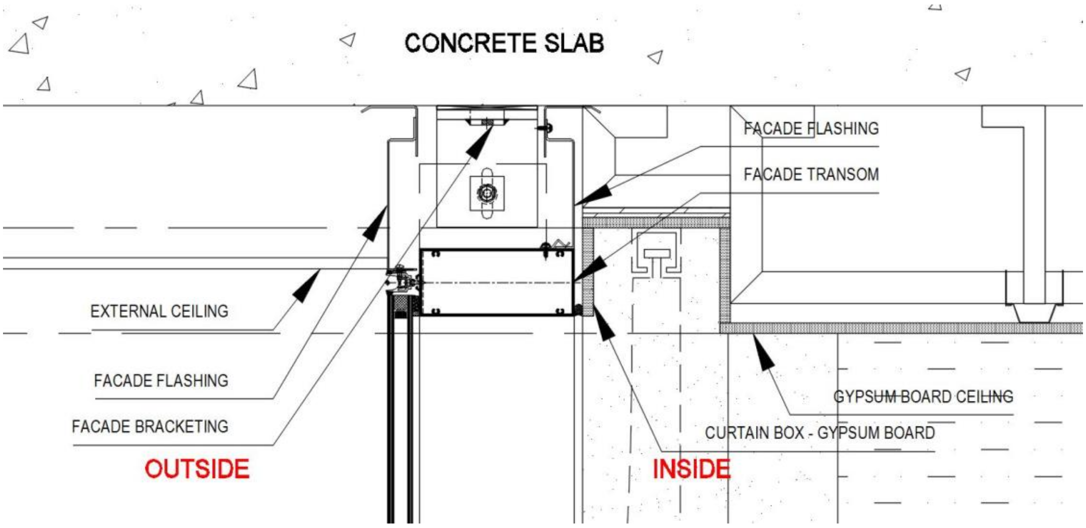


*Figure 7 : Detail illustrating interior ceiling and facade interface (Author)*

The logical order of precedence in construction sequence would be the installation of the façade brackets, framing and flashing at least prior to the installation of the interior ceilings. This is to ensure that there will be no further access requirements to the façade bracket area by the façade contractor should the ceiling work commence. The other scenario where the ceiling work would start before the façade works will result in either having the ceiling contractor coming back to close a leave out areas or to rectify damaged areas of the ceiling which are the result of the façade contractor carrying out his work.

- Lack of resources.

This can be the result of poor financial planning, poor construction planning (Aiyetan & Das, 2015), delays in the project delivery and delays in client interim payments possibly resulting in increased work pressure on the labor force (Paté-Cornel, 1990). This can occur since late procurement of materials to carry on a task will delay the commencement of the same task, forcing the construction teams to attempt to conclude the task in a shorter duration than planned or to try to execute it in parallel to the succeeding task. Such scenarios will leave more room for errors and rework on site (Arashpour, et al., 2013) as well as demoralize the workforce (Simpeh, 2012).

Furthermore, such conditions as an impact of rework would result in events where labor forces who are executing a task have no relevant experience to the task in hand. This is since workers with the relevant experience are required to execute the same task but in a different zone or floor at the same time (Case D in Figure 8). Such scenario would potentially cause a slower progress of work than anticipated and often with lower quality. Otherwise, the only option to accommodate the delay of rework is to extend the overall duration of the project (Case C in Figure 8) which is not feasible both environmentally and financially, as it will potentially cause more rework (Low & Goh, 1994).


*Figure 8 : Simplified relationship between project delivery plan and rework impact (Author)*

- Lack of or poor planning.

This can be the result of lack of experience including unfamiliarity with the construction methodologies and standard practices (Aiyetan & Das, 2015), the unavailability of information concerning lead time durations of critical items, construction task durations and labor force availability (Arashpour, et al., 2013), the absence of an agreed sequence of work (coordination between different activates) (Touran, 2010) and the unfamiliarity with the design. This would result in lack or unavailability of resources, materials, equipment and labor force, pressured construction schedule (Waldron, 2006), limited options in material selection since long lead items may no longer be viable due to time constraints (Gündüz, et al., 2013), delays in construction progress and project delivery (Love, et al., 2004) and disruption induced on the financial system of the project due to unanticipated work load or resource requirement.

- Poor quality control implementation and support.

This can be the result of lack of experience (Aiyetan & Das, 2015), lack of knowledge and awareness (Low & Goh, 1994), poor managerial attitude towards quality procedures and its implementations (Serpell, 1999), difficulty in justifying quality plans viability due to lack of reporting and documentation of rework and nonconformance records. This is usually combined with the often attempt of the contractor to hide nonconformance and sometimes rectify it while considering it as part of tolerance allowance (Al-Tmeemy, et al., 2012).

Furthermore, pressured construction schedule will lead to the bypass of quality checks and procedures (Rodchua, 2006). Moreover, delay in issuing inspection requests and inspection feedback along with insufficient quality related staff can cause poor quality control. This will create larger scope of rework especially in the event of long inspection cycles or delay in raising inspection as more work can be done prior to the identification of a problem (Chen & Luo, 2014).

Additional causes of poor quality control include poor workmanship and poor financial planning (not enough allowance for quality control implementation).

- Failure to learn from previous mistakes

This can be the result of lack of reporting of nonconformance which can be the result of construction program pressure, lack of experience, lack of awareness (Dehnavi, 2015), poor implementation of quality procedures and the fact that contractors are usually busy with the upcoming task or project, which leaves no time to go through and attempt to understand what went wrong in the previous task/project and why it happened limiting the benefit of learning by execution (Love, et al., 2004).

This would result in delay in construction activities which would impose workload and financial pressure on the project's team leading to errors and rework while denying its significant benefits (Love, et al., 2015).

- Poor managerial qualities in construction.

This can be the result of lack of experience (Wong, et al., 2001) and lack of awareness of the causes of rework and their impact on project progress (Al-Tmeemy, et al., 2012). This would result in out of sequence works which would encourage rework in construction leading to financial and schedule pressures on the project. Furthermore, it will direct the focus of the construction teams on execution aside from quality (Aiyetan & Das, 2015).

It should be noted that all the factors whether being design related or nonconforming execution related share a common aspect which is the fact that they all originate partially or fully from information. This is whether due to information's creation, accuracy, rectification, accessibility or absence (Dave, et al., 2016). Lack of labor force for example as discussed can be a result poor financial planning. This can be the result from lack or inaccuracy of information such as unavailability of productivity rates of labor force due to uncertainty of their skill level. Furthermore, lack of understanding of the project's design due to inaccurate representation, miss-coordination or error can lead to poor construction planning. Which in return would cause lack of labor force on site since the extent of the scope to be executed was not fully comprehended. Therefore, controlling information flow in its different forms whether as design drawings, a task duration or the current progress of an activity on site is crucial to reduce rework in construction (Dave, et al., 2010).

In summary of the previous sections within this chapter, Appendix A illustrates a table which indicates the previously mentioned causes of rework along with the division within the construction industry that is responsible for each cause. In alignment with the aims and objectives of this research, causes created by the contractor's design teams (noted as "Design (Contractor)"), execution related causes (noted as "physical execution") and planning related causes (noted as "planning") will be addressed within the scope of this research. However, these causes will all be evaluated within this research to serve as a base for future research.

While studying the rework causes in their different categories, the origin of each will should be identified in order to conclude the causes that are within the contractor scope. The sources will be grouped as the following:

- Design by contractor: all design scope undertaken by the contractor including technical review, shop drawing preparation and coordination.
- Design by others: this includes the design inputs done by the client and the consultant.
- Physical execution: causes that can impact the physical construction directly.
- Planning by contractor: causes that has to do with the planning of the construction activities along with information management and deliverables on site.
- Planning by others: causes that has to do with the planning of the information management and deliverables by the client, consultant and relevant external entities.
- Financing by contractor: causes that impact the cash flow within a project in a way that impact design deliverables and construction activities from the contractor's side.
- Financing by others: causes that impact the cash flow within a project in a way that impact design deliverables and construction activities from the client's/consultant's side.

The factor of Poor communication between the client and the consultant during the design briefing and between the lead consultant and the sub-consultants during the design stage will be grouped under "Design by others" and "Financing by others". This factor is grouped under "Design by others" because it is about the communication between the project's parties before the contractor is involved. Furthermore, poor communication between the client and the designers / consultants can happen due to limited budgetary. This can result in the employment of inexperienced client representatives or design coordinators which is why this factor is grouped under "Financing by others".

Lack of relevant or sufficient expertise within the assigned design/technical teams factor will be grouped under "Financing by contractor" and "Financing by others". This is because both clients and contractors seek to drive down cost in any possible way. Choosing an inexperienced design team is one of these ways which in turn can lead to faulty contract documents, unmet design intents or inaccurate shop drawings.

Design is set to be executed with certain systems and construction techniques that are outdated factor will be grouped under "Design by others". This is because consultants in most cases fail to keep themselves updated with latest execution technologies. This is since it requires less effort for the consultant to adopt a detail that was used in a previous project rather than check for updated or more viable execution detail.

Unanticipated design load and design changes due to errors and missing information factor will be grouped under "Design by contractor", "Design by others" and "Physical execution". It is grouped under "Design by contractor" since errors could happen during the coordination stages and while preparing shop drawings. These errors can come back and become an unanticipated load which would affect the planned design processes within the contractor's technical team. Furthermore, this factor was grouped under "Design by others" as the consultants can commit mistakes which can have an impact on coordination processes pre-contract and post-contract award. Lastly, this factor is also grouped under "Physical execution" as contractor usually attempt to preserve a wrongly executed element and try to amend the design to suit the existing condition. This is because the contractor is trying to avoid the cost of demolishing and rebuilding the element which is usually more than the cost of the virtual rework required to adopt such mistake.

Competitive bidding from the consultant factor will be grouped under "Financing by others". This is because this factor has to do with consultants providing low offers to try to win projects. Such low offers can have a knock-on effect on the quality of the work being delivered.

Time boxing; which is basically setting a fixed duration for a design task regardless of its final status being completed or not factor will be grouped under "Design by contractor" and "Design by others". This factor is grouped under "Design by contractor" since contractors may not spend the required duration of time to allow for checking the produced information thoroughly. Mostly because this duration may be longer than originally anticipated and planned. Furthermore, this factor is grouped under "Design by others" since clients and consultants may not spend the required duration of time to properly create and check a design brief or contract documents.

Misalignment between information readiness and construction activities factor is grouped under "Design by contractor" and "Planning by contractor". Contractors' design teams are mainly responsible to prevent such misalignment from occurring. These teams should make themselves familiar with the construction programs and plan their deliverables accordingly which is why this factor was grouped under "Design by contractor". Furthermore, a key role of planners on a construction site is to monitor progress. Therefore, they should keep an eye on the progress of design deliverables and notify relevant parties should any delay is perceived. Which is why this factor was grouped under "Planning by contractor".

Suppliers or subcontractors not on-board with the construction due to un-concluded commercial issues factor is grouped under "Financing by contractor". This is since technical departments are not allowed to engage a scope unless the same is commercially acceptable by their management to avoid abortive work. This will force the technical teams within the main contractor to proceed with available information from the contract documents by the consultant which may not be accurate.

Preference to use locally available materials factor is grouped under “Financing by contractor” and “Planning by contractor”. This factor is grouped under “Financing by contractor” because local materials are usually cheaper and easier to source compared to non-local materials. Hence why managers in the contractor side choose to propose the same and modify the design with the same to reduce overall cost. Furthermore, such scenario can be proposed by the contractor to catch up with the construction program in a delayed construction event. This is since the material lead time was shortened because it was locally sourced. Which is why this factor was grouped under “Planning by contractor”.

Change in construction methodology factor is grouped under “Physical execution” and “Financing by contractor”. This factor is grouped under “Physical execution” since changes to design can happen at the wish of the contractor to follow an easier to execute construction detail. This usually happen in agreement with the consultant and the client. Furthermore, this factor is grouped under “Financing by contractor” since reducing cost is usually a motive to initiate a design change to the construction design and detailing. An example for the same would the change of a concrete stair case from cast in situ to precast. The latter requires significantly less manpower and is characterized with speedy construction process in comparison to the former. Therefore, it would be a logical option for the contractor to propose proceeding with precast stairs rather than the specified cast in situ saving cost and time.

Rectification of construction non-conformance and errors factor is grouped under “Design by contractor”, “Design by others” and “Physical execution”. This factor is grouped under “Design by contractor” since construction non-conformances can be caused due to errors in the coordination processes by the contractor’s technical teams. Furthermore, it is grouped under “Design by others” since constructed non-conformances can be caused by contractors following faulty contract documents produced by the consultants. This can happen if there are errors or mistakes in the contract documents which will be translated into physical errors once constructed on site. Lastly, this factor was grouped under “Physical execution” as construction non-conformances can happen simply due to wrong execution despite the base information being correct.

Insufficient use of information technology factor is grouped under “Design by contractor”, “Design by others”, “Physical execution”, “Financing by contractor” and “Financing by others”. This factor is grouped under “Design by contractor” since effective information technology implementation is the responsibility of the contractors’ technical teams. This same extends to the clients’ and the consultants’ technical teams and the site teams which is why this factor is grouped under “Design by others” and “Physical execution”. Lastly, this factor was grouped under “Financing by contractor” and “Financing by others” since commercial aspects are usually the first barrier against the implementation of latest information technology in a project.

Changes of design induced by client factor is grouped under”Design by others” and “Financing by others”. Interaction of the client with future/potential tenants can force him to change the design to make the final product more appealing to the tenants. This is why this factor is grouped under “Design by others”. Furthermore, financial issues within the client organization can obstruct cash flow in a construction project. This obstruction can result in the client requesting the contractor to perform a value engineering exercise in order to reduce cost. This exercise will create design changes which can cause rework as a result. Which is why this factor grouped under “Financing by others”.

Inadequacy in the preparation and the communication of the design brief and project objectives factor is grouped under “Design by others” and “Financing by others”. This is since the responsibility of the preparation of a design brief as well as its effective communication to the consultants falls with the client. Furthermore, this factor is grouped under “Financing by others” since budget usually have an effect on the appointment of experienced staff who would prepare the design brief. Moreover, it will impact the selection of consultants who in turn will translate the brief into contract documents and supervise the translation of the contract documents into a physical product.

Financial problems faced by the client factor is grouped under “Financing by others”. This is since this factor has an impact on the cash flow in a project which may force a decrease in productivity due to insufficient funds. Furthermore, such financial problems can force the client to request design changes to achieve value engineering in the project.

Client’s indecisiveness factor is grouped under “Design by others”. This is since indecisiveness from the client can cause work to stop on site due to absence of a finalized design intent. Which in turn will add work pressure going forward in the project as more work needs to be carried out in less time once the intent is finalized. This will eventually lead to rework.

Client’s insistent nature factor is grouped under “Design by others”. This is since clients usually push the consultants to issue the contract documents despite being incomplete to allow construction to commence. Which in turn will force the consultants to issue further revisions to the design as the design development matures inducing design changes and potentially rework.

Insufficient funds allocated to site investigations factor is grouped under “Design by others” and “Financing by others”. This factor was grouped under “Design by others” since for a consultant to properly undertake their design scope, they should request the client to provide an “as-built” condition of the site. Furthermore, they should incorporate any temporary works by third parties such as a piling / excavations contractor into the construction documents where required. This factor was grouped under “Financing by others” as clients should provide an allowance for the the consultants to incorporate the works of other parties such as piling/excavation contractors into the design. This includes reviewing temporary openings within structural elements to allow temporary elements such as struts supporting shoring to exist for as long as required.

Limited client involvement in the project factor is grouped under “Design by others” and “Financing by others”. This factor is grouped under “Design by others” since the absence of feedback from clients about the design can cause problems as the design matures. This is since the client is not keeping himself up to date with the progress of the design. Therefore, the client may request changes in a late stage inducing rework. Furthermore, this factor is grouped under “Financing by others” since cost reduction can be the reason for clients to limit interaction with consultant as they don’t want to spend money hiring relevant staff early on in the project as discussed previously in this chapter.

Low design service / contract documentation preparation payment factor is grouped under “Financing by others”. It is grouped under “Financing by others” since limiting budget expenditure by both the client and the consultant is one of the causes leading to this factor. This scenario can lead to poor construction documentation potentially leading to both virtual and physical rework

External factors of design changes are grouped under “Design by others” since these design changes are forced on all the stakeholders of the project including the client.

Limited access to latest information by the construction teams factor is grouped under “Design by contractor” and “Design by others”. It is the duty of the contractor’s technical teams to ensure site teams have access to latest information. Which is why this factor was grouped under “Design by contractor”. However, usually the main cause for the unavailability of latest information is due to missing information from the consultant’s contract documents. Which in return will hinder the processes of coordination and shop drawing creation. Preventing the creation of the necessary information for site activities to proceed. Which is why this factor was grouped under “Design by others”.

Lack of experienced and skilled labor force factor is grouped under “Financing by contractor” and “Planning by contractor”. Grouping this factor under “Financing by contractor” is since cost cutting can be one of the main causes for poorly experienced labor employment. Furthermore, poor planning can create the events where the site is ready for an activity to commence but there is no planned labor force to undertake this activity. This will force the contractor to utilize whatever labor he has or hire from a man power supplier to take advantage of such opportunity. However, the available labor force may not be experienced enough in the activity that they about to undertake. Which can cause lower quality execution and may cause rework in the future. This is why this factor is also grouped under “Planning by contractor”.

Project budget pressure factor is grouped under “Financing by contractor”. This is since poor financial planning can cause site activities to halt should there be a blockage in cash flow. This is due the role of poor financial planning in creating project budget pressure. Furthermore, this factor can be the cause of poor tendering which may cause underpricing. This can lead to the attempt of the contractor to cut cost in materials or labor which increases the probability of rework creation.

Poor quality of information is grouped under “Design by contractor”, “Design by others”, “Planning by contractor” and “Planning by others”. The reason for grouping this factor under “Design by contractor” is because the technical team within a contractor contributes to a large portion of the information created and communicated on a construction site. The same is applicable to the information released by the consultants as they form the base of the contractor’s work. Which is the reason why this factor is grouped under “Design by others”. Furthermore, this factor is grouped under “Planning by contractor” and “Planning by others” since poor planning can cause pressured information release which can negatively impact the information quality. This can ultimately result in both virtual and physical rework. Moreover, planning can be infected by bad information since incorrect sequencing, incorrect durations, incorrect prerequisite requirements and wrong site progress reports can be incorporated into the project’s planning. This wrong information can present a misleading picture to the planning teams and the project’s management which can captivate them from taking corrective actions in return should any issue arise.

Lack of discipline (working out of sequence) factor is grouped under “Design by contractor”, “Design by others”, “Physical execution”, “Planning by contractor” and “Planning by others”. The design and coordination activities by the contractor’s technical teams can happen before prerequisite information is ready. This will force them to start based on outdated information as what will be discussed in the coming chapters causing virtual rework. This is why this factor is grouped under “Design by contractor”. The same is applicable to design and coordination activities carried out by the consultants in the preparation of contract documents. Which is the reason this factor is grouped under “Design by others”. Furthermore, this factor is grouped under “Physical execution” since work shouldn’t commence unless prerequisite works were done as discussed previously in this chapter. The planning of activities on site or in design can help reduce out of sequence works which can in turn reduce physical and virtual rework. Therefore, this factor was grouped under “Planning by contractor” and “Planning by others”.as well.

Lack of resources factor is grouped under “Planning by contractor”, “Planning by others”, “Financing by contractor” and “Financing by others”. Anticipating required resources to carry on physical or virtual activities by all stakeholders is a key objective of planning processes. Therefore, this factor was grouped under “Planning by contractor” and “Planning by others”. Furthermore, this factor was grouped under “Financing by contractor” and “Financing by others” since poor financial planning may hinder resources supply. This in turn can halt both construction and design/technical activities. Which in turn may cause delay and project pressure eventually leading to rework.

Lack of or poor planning factor is grouped under “Planning by contractor”, “Planning by others”, “Financing by contractor” and “Financing by others”. This is since construction and design/technical activities planning as well as financial planning both play a significant role in inducing rework if not carried out properly. The same is applicable to the client, consultant, and contractor.

Poor quality control implementation and support factor is grouped under “Planning by contractor”, “Planning by others”, “Financing by contractor” and “Financing by others”. This is grouped under “Planning by contractor” and “Planning by others” since incorporating quality related activities in the sequence of design and construction activities is an important aspect in project planning. Failure to achieve the above-mentioned aspect can jeopardize the flow of activities in a project both virtual and physical. Furthermore, this factor was grouped under “Financing by contractor” and “Financing by others” as usually financial planners don’t pay much attention to quality related activities or staff. This will cause a reduction in quality levels on in design documents and on construction site as less quality related activities are being done.

Failure to learn from previous mistakes factor is grouped under “Design by contractor”, “Design by others”, “Physical execution”. This factor is also grouped under “Planning by contractor”, “Planning by others”, “Financing by contractor” and “Financing by others”. This is because learning from past experiences or from others can significantly help the performance of each group. Resulting in reduced rework.

Poor managerial qualities in construction factor is grouped under “Physical construction”. This is since enforcing standards for construction and quality procedures will not happen unless site management support them. Should this support become absent, site teams can disregard work quality notions and focus on work quantity.

Lack of awareness of the scope of work of each entity within contractors and subcontractors factor is grouped under “Design by contractor” and “Planning by contractor”. The design of specialty items within the contractor is usually managed by the technical teams within the contractor. These technical teams follow up on the progress of the design of different specialized items from specialized suppliers /subcontractors. Therefore, these technical teams need to be aware of what is required to alert management/commercial teams of the requirement to appoint subcontractors to commence coordination processes. This is why this factor was grouped under “Design by contractor”. Furthermore, planning ideally requires complete awareness of the construction scope for it to work. This is since planning need to encompass all construction activities for it to provide an accurate progress update and an accurate estimated finish date. These construction activities extend to activities that are not design related such as logistics or concrete shuttering, etc. Which is why this factor was grouped under “Planning by contractor”.

Missing and inaccurate information in the design documents (contract docs and construction shop drawings) factor is grouped under “Design by contractor” and “Design by others”. This is since poor undertaking of design activities by the consultant and/or the contractor’s technical teams can lead to both physical and virtual rework.

*Table 1: Summary of the causes of rework as identified in the literature review*

| No. | Cause | Design (Contractor) | Design (other) | Physical Execution | Planning (contractor) | Planning (others) | Financing (contractor) | Financing (others) |
|---|---|---|---|---|---|---|---|---|
| 1. | Poor communication between the client and the consultant during the design briefing and between the lead consultant and the sub-consultants during the design stage | | √ | | | | | √ |
| 2. | Lack of relevant or sufficient expertise within the assigned design/technical teams | | | | | | √ | √ |
| 3. | Design is set to be executed with certain systems and construction techniques that are outdated | | √ | | | | | |
| 4. | Unanticipated design load and design changes due to errors and missing information. | √ | √ | √ | | | | |
| 5. | Competitive bidding from the consultants | | | | | | | √ |
| 6. | Time boxing; which is basically setting a fixed duration for each design task regardless of its status being completed or not | √ | √ | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7. | Misalignment between information readiness and construction activities. | √ | | | √ | | | |
| 8. | Suppliers or subcontractor not on-board with the construction due to un-concluded commercial issues | | | | | | √ | |
| 9. | preference to use locally available materials | | | | √ | | √ | |
| 10. | Change in construction methodology | | | √ | | | √ | |
| 11. | rectification of construction non-conformance and errors | √ | √ | √ | | | | |
| 12. | insufficient use of information technology | √ | √ | √ | | | √ | √ |
| 13. | Changes of design induced by client | | √ | | | | | √ |
| 14. | Inadequacy in the preparation and the communication of the design brief and project objectives | | √ | | | | | √ |
| 15. | Financial problems faced by the client | | | | | | | √ |
| 16. | Client's indecisiveness | | √ | | | | | |
| 17. | Client's insistent nature | | √ | | | | | |
| 18. | Insufficient funds allocated to site investigations | | √ | | | | | √ |
| 19. | Limited client involvement in the project. | | √ | | | | | √ |
| 20. | Low design service / contract documentation preparation payment | | | | | | | √ |
| 21. | External factors of design changes | | √ | | | | | |
| 22. | Limited access to latest information by the construction teams | √ | | | | | | √ |
| 23. | Lack of experienced and skilled labor force | | | | √ | | √ | |
| 24. | Project budget pressure | | | | | | √ | |
| 25. | Poor quality of information | √ | √ | | √ | √ | | |
| 26. | Lack of discipline (working out of sequence) | √ | √ | √ | √ | √ | | |
| 27. | Lack of resources | | | | √ | √ | √ | √ |
| 28. | Lack of or poor planning | | | | √ | √ | √ | √ |
| 29. | Poor quality control implementation and support | | | | √ | √ | √ | √ |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30. | Failure to learn from previous mistakes | √ | √ | √ | √ | √ | √ | √ |
| 31. | Poor managerial qualities in construction | | | √ | | | | |
| 32. | Lack of awareness of the scope of work of each entity within contractors and subcontractors. | √ | | | √ | | | |
| 33. | Missing and inaccurate information in the design documents (contract docs and construction shop drawings). | √ | √ | | | | | |

## 2.3. Information flow and knowledge management in construction:

### 2.3.1. An introduction to knowledge management:

The concept of knowledge management has been discussed in literature for around two decades especially when it comes to management literature (Kale & Karaman, 2012). Therefore, it has been defined in multiple occasions as “a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information.” (Davenport & Prusak, 1998). Another definition is “the integration of information, ideas, experience, intuition, skills and lessons learned that creates added value for a firm.” (Dana, , et al., 2005).

Knowledge management arguably was the result of knowledge diversity where literature have attempted to capture that nature with its different origins and influences by categorizing it as different types. These types include the following (Alavi & Leidner, 2001):

- Procedural knowledge (familiarity with how something will take place).
- Declarative knowledge (familiarity with what is the nature of something).
- Conditional knowledge (familiarity with when something is to take place).
- Causal knowledge (familiarity with why something took, is taking or will take place).
- Relational knowledge (familiarity with what accompanies a certain event when it happens).

Literature also attempts to categorize knowledge from an experience point of view and it divides it into two categories (Nonaka, 1991):

- Tacit knowledge: knowledge context is personal and difficult to explain.
- Explicit knowledge: knowledge that can be confined and illustrated thoroughly with symbolic representation such as a mathematical equation.

The management aspect of the knowledge was defined in the literature as the formation and the successive management of the platform that provokes knowledge formation, distribution, awareness and organization for the advantage of a certain entity (Sarrafzadeh, et al., 2006). The effectiveness of knowledge management process depends heavily on knowledge management possession of certain established targets. Literature discusses the goals of knowledge management and describes them as the means to maintain competitive advantage (Wiig, 1997) which can be achieved through the following (Kale & Karaman, 2012):

- Financial perspective: Improving return on investments and improving profit.
- Process perspective: improving the provided services through the optimization of different related processes.
- Market perspective: maintaining market viability and be on the lookout for new projects.
- Costumer perspective: Improving costumer's satisfaction with the services provided.

Knowledge management comprises of knowledge management processes and knowledge management enablers (Kale & Karaman, 2012). The knowledge management processes are defined as knowledge management implementation models such as the "knowledge spiral" (Nonaka, 1991) which basically focuses on how knowledge in its different types gets communicated and how it evolves into different types. "Knowledge Cycles" model (Wiig, 1993) where the focus is more on knowledge conceptualization and then its utilization by different parties. These models were developed further to include sub-processes for knowledge management which includes acquisition (obtaining or producing information), conversion (communication of information between different parties), application (utilization of information in the action of a task or process) and protection (preventing poor utilization of information, its loss and thievery) (Gold, et al., 2001). Knowledge management enablers are the instruments in an organization which provoke and nurture the creation, distribution, growth, application and protection of knowledge, they are divided into two categories; the first being the social enablers such as the users and the organizations handling the knowledge which gets influenced by their behavior and their structure, the second being the technical enablers which are the tools that social enablers use to enable knowledge processing and management.

### 2.3.2. Knowledge management in construction:

Knowledge in construction is created by design intents, design briefs, contract documents and specification, specialist systems and detailing, lessons learnt, etc. It is conversed between designers, managers, contractors, detailers, quantity surveyors, authority engineers, engineers for other or future jobs, etc. It grows as knowledge is gathered from experience in past projects and the experience of the social enablers involved in a project. It is applied in construction of physical elements, the detailing and development of design intents, the creation of delivery and tracking schedules, etc. It is protected through the storage of information on the cloud, allowing access to certain information to authorized parties only, etc. Such characteristics clearly indicate a significant role in the construction process where its malfunction can cause serious damage to project progress both during design and during construction.

The platforms of knowledge management in construction have varied throughout the time. They have developed from the transfer of hard copies of information such as drawings, material submittals, inspection requests, etc. (Klein, et al., 2012). Up to the adoption of cloud based construction documentation management systems such as ACONEX ™. Such systems allow project documents to be uploaded with updated status when applicable while keeping records of previous states of a document for future access (Zhai, et al., 2009).

### 2.3.3. Information flow within construction:

Information flow process on a construction site can include multiple cycles. An example would be the information cycle between the contractor, the consultant and the client which has to do with processing documents for approval, issuing change orders, etc. Another cycle encompasses information exchange under the umbrella of the main contractor to facilitate construction activities and internal coordination. These cycles can overlap at certain points, as an example, the two cycles discussed earlier overlap at the contractor technical team area and the QA/QC team area. This is since the technical team usually manages the submission of information processes, follows up on approvals from the consultant and the client and circulate the approved information to the site teams for construction. Whereas the QA/QC team raises physically completed items to the consultant or client for final inspection and approval as well as receives approval requests from site teams. These two cycles are employed in a linear process as it starts from the technical team of the contractor, the technical team processes the information received from the consultant or client as contract documents and subcontractors or suppliers information into shop drawings, material submittals, method statements, etc. Furthermore, the team submits the processed information for approval.

Subsequently, the consultant and sometimes the client review the submitted information evaluating its alignment with the contract documents, standard code of practice and construction methodologies. Then, they either approve authorizing construction or reject the submission for the contractor’s technical team to revise and resubmit as per the comments. Some projects employ conditional approval status where work may progress subject to incorporation of comments on the submitted document to speed up the commencement date of construction activities.

The approved (or conditionally approved) document then gets circulated by the technical team to relevant site personals for construction and the QA/QC team for information. The QA/QC team will be undertaking inspection tasks based on a predefined and agreed sequence of work depending on the task that is being carried out. The team then will provide rejection for nonconforming application and approvals for conforming items in line with the approved information for the consultant/client. Approved physical elements are then inspected by the consultant and the client as part of project handover process.

In addition to the previously discussed cycles, there are other cycles that comprise a construction project, such as the planning cycle where planners can monitor progress by an exchange of information with other teams containing the status of different activities. Another example would be the logistics cycle where teams would request access to a certain area or a method of material transportation or material storage area within the site.

As discussed, the information flow process within a construction site comprises of cycles, these cycles in turn consist of sub processes where their nature would vary. Such variance will depend on the project delivery methodology and the agreed dynamics of responsibility distribution among the project parties. For example, the main contractor usually submits shop drawings for approval in a design-bid-build project delivery methodology but may not require to do the same in a "design and build" project delivery methodology. This is since specialist subcontractors and suppliers were involved in the formation of the contract documents which eliminate the need for design development processes during the construction stage of a project.

These sub processes can include the following:

- Interpretation and review processes carried out by the technical teams of the contractor and the subcontractors for the contract documents. This is to ensure any problems such as missing information, miss-coordination, clashes and non-workable details are identified, communicated to the consultant and client and are actually resolved prior to construction commencement.
- Carrying out coordination processes which happen during the information preparation stage between the contractor's technical team and the subcontractors (including sometimes the consultant depending on the

project delivery method) where a dynamic exchange of information takes place depending on the scope, package, complexity of the scope and what other trades and disciplines require to interface.

- The submission of the prepared information to the relevant parties which usually follows a predefined approval cycle governing the duration that a document would spend being under-review by each party. This would help identifying a time line for information preparation and make ready to execute on site.
- The distribution of processed information (whether approved or rejected) to relevant parties whether for revision purposes, further coordination task or for construction purposes. Depending on the task, certain information can or must be shared prior to approval with certain parties to ensure the availability of resources and materials for the work to commence upon receiving approved information. An example would be a material submittal for glazing for a project's façade, the required glass can't be identified unless the criteria for its selection is set which is basically the first round of information circulated to potential suppliers. This is then followed by the selection of a supplier whose product will be submitted as a material submittal document to the relevant parties to obtain approvals. In parallel, an ordering process commences where the order information will be communicated but not authorized pending submittal approval. Once the submittal is approved, the order is authorized and placed. The order initiation step would help save time on site to allow activities to start on time.

  Furthermore, information is usually shared prior to approval to allow planning to take place helping construction teams identify potential problems and constructability issues, arrange resources, define and agree on a sequence of work where different trades are interfacing, obtain clear access to relevant area, etc.
- Monitor construction progress to have a fast response should work pressure starts to build up.
- The commencement of QA/QC inspection processes where delivered materials, ongoing and completed work is evaluated against project

requirements. Furthermore, providing the approved completed work to the consultant and client to commence the "Snagging" process.

- The consultant and the client commence the Snagging process highlighting problematic or unsatisfactory items in the areas raised for inspection wherever relevant or accepts the physical product status and the handover of the product from the contractors. This will constitute the end of the construction process and the information flow process for that particular item in that particular stage.

As discussed, the information flow in the construction process is considered a crucial part pf the project delivery process and its proper implementation is key to the project's success in avoiding different causes of rework. A key factor for the success of information flow is the platform the information is flowing through which has been developing as discussed earlier despite being rarely documented or studied (Dave, et al., 2016).

Khan, et al (2015), Soibelman & Kim (2002) and Baldwin, et al (1999) all agreed that information flow plays a significant role in determining the success of a construction project. Dave, et al (2014) and Wang, et al (2016) clarify that an efficient production management strategy relies heavily on proper information with its promptness and accuracy.

Literature categorizes the information management strategies controlling the flow of information as either "push" system or "pull" system (Otjacques, et al., 2003). The former provides the information upon a demand and the latter would release information based on an alternation in system status or due to the occurrence of an event within the information related context (Caldas & Soibelman, 2002). There are two types of information flows when it comes to production management as illustrated in Figure 9. Information is employed for both planning activities ahead (indicated in green) and for execution and control of production processes (indicated in blue). There is an integrated upstream path of information from the production / control group back to the planning group, which boost the reliability of the provided information (Howell & Ballard, 1996).

A simplified example of this system in action is the educated assumption by the planning department that it will take a team of three masons 2 days to complete the construction of a 10sqm wall. Based on that assumption, materials have been procured and labor force have been assigned for the work to commence. Site and operation teams commence the work on site and finish the task in 3 days. Such elongation in duration is then up-streamed back to the planning department to adjust their projections. The adjustment will either allow the increase in the durations of similar tasks in the future or assign more labor force to achieve the target date.

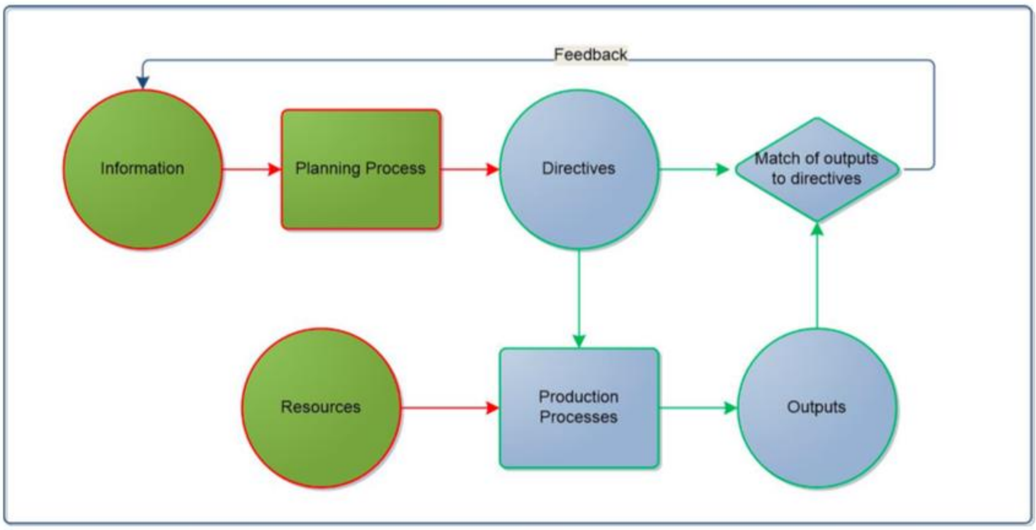


*Figure 9 : Relationship between planning and control (Howell & Ballard, 1996)*

The cause of poor information flow management is the fact that projects are usually managed by what is known as "high-level" approach, it is characterized by specifics that are not addressed sufficiently for proper integration into the project program. This gets further complicated by the increased number of stakeholders involved in a project (Laufer & Tucker , 1987). Furthermore, the reliance on exchange of verbal information without the implementation of a system to track production performance and/or activities can cause inaccuracy and confusion within any information system. The same result can happen where different stakeholders implement different information management systems (Formoso, 1991). Moreover, there is a strong focus by the managerial body on the deliverables of a task or project where the same is absent for production process which reduces the visibility of any problems in the production flow and only highlights a delay or problem in final delivery.

### 2.3.4. BIM as knowledge management tool:

Building information modeling (BIM) has been identified and used as a platform for different parties of a project for information creation, processing and transferring (Maher, 2008). It is defined as the application of virtually constructed building models that are rich in information which are used to develop design and construction solutions, aid in the preparation of design documentation and evaluate the processes and activities of construction (Kivits & Furneaux, 2013). It granted instant access to all project information, which proved to facilitate design error detection and resolution (Vanlande, et al., 2008). This would help blur the boundaries between different parties of a project improving both collaboration (Kymmell, 2008) and performance (Arayici, et al., 2011) which would help reduce waste (Azhar, 2011). BIM uses intelligent objects which have the capability to store data compared to lines out of 2D CAD drawings which have significantly less flexibility in storing non-geometric information. This plays a crucial role in improving design productivity and quality (BARISTA, 2009) and the prevention of misinterpretation of information. This extends to the capability of creating photo-realistic imagery which enhances the perception of spatial configurations of different building components.

BIM tools have also extended their applicability as construction/production management tool. Data rich models have been used through the implementation of certain applications as means to provide insights to current status of construction in a project (refer to Figure 11 and Figure 12). Such type of information has significantly helped decision makers on construction sites to detect issues of concern which may jeopardize work progress or may cause schedule pressure.

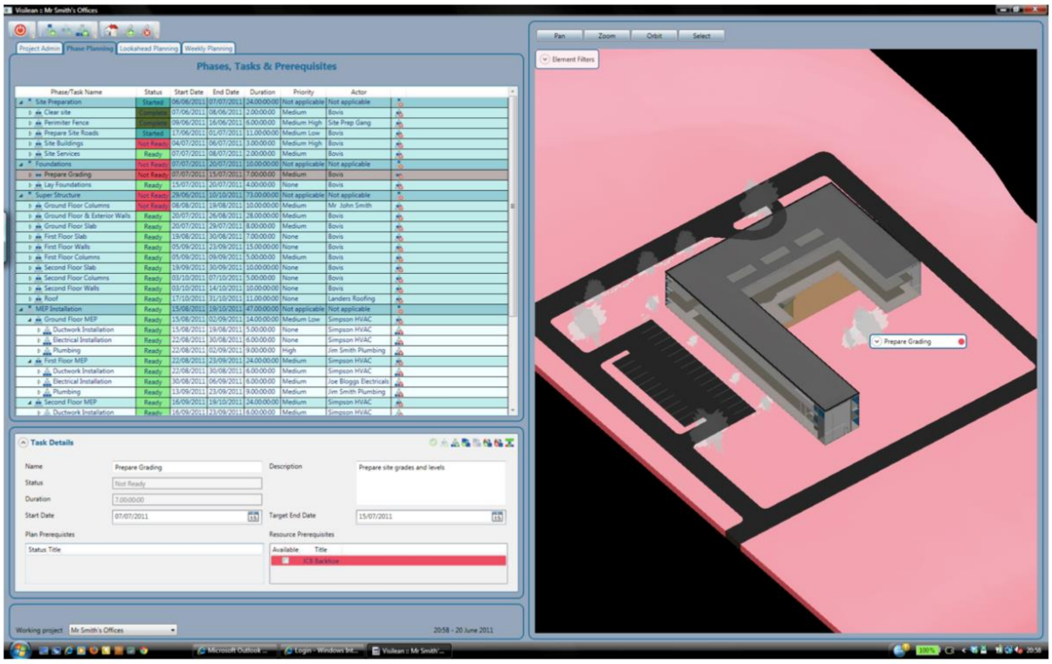


*Figure 10 : Phase Planning in VisiLean (Dave, 2013)*

There are various types of construction/production management systems where each have attempted to satisfy certain information related needs in a construction site such as VisiLean (Dave, 2013)(refer Figure 10), KanBIM (Sacks, et al., 2010) (refer Figure 11) and CONWIP (Sacks, et al., 2009)(refer Figure 12). These systems also provided an interface of some extent to Building Information Modeling in an attempt to ensure alignment of planning, execution and control information with the project information. Yet, they still lack interoperability between information systems of different stakeholders (Dave, et al., 2014).


*Figure 11 : Trade crew leader work status and reporting interface in KanBIM (Sacks, et al., 2010)*

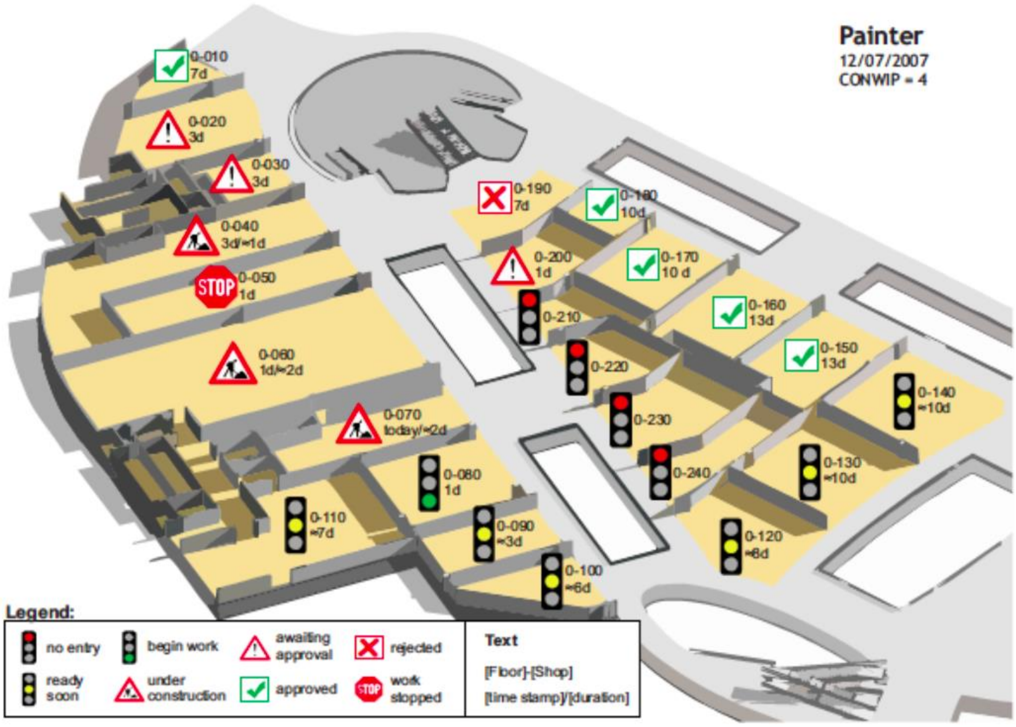


*Figure 12 : 3D visualization of past, present and future work using CONWIP (Sacks, et al., 2009)*

These systems almost employ the same logic or sequence on how information is presented and to whom it is communicated during different stages of a work-in-progress task with a combination of both manual and automated inputs.

What needs to be noted is that the three mentioned systems could've satisfied some if not all of their objectives without relying on a direct link with BIM. This is since the reporting of the status of work can take place with simple indication of zone, floor, room and status on a simple spreadsheet hence the reason for the added complexity to the process seems unclear. Furthermore, the reviewed tools don't seem to entertain the design stage of a project where such concepts can play significant roles in providing real-time update on the status of the design for all stakeholders and to track unresolved issues in the design by the management.

# Chapter 3: Research methodology

This chapter will go through different methodologies that were utilized by other researchers in similar topics. The study will highlight both advantages and disadvantages of each of the studied methodologies. The purpose of this evaluation is to determine the most appropriate methodology to carry out the objectives of this research. The methods proposed for this research are survey, case study, interviews and design science research. There are other methods which researchers have used in similar topics such as literature review and field observations.

## 3.1. Methods adopted by other researchers in similar topics:

Research strategy is defined as "the general plan of how the researcher will go about answering the research questions" (Saunders, et al., 2009). The methodologies utilized by other researchers to research similar topics include literature review, survey, case studies, interviews, design science research methodology and field observations.

### 3.1.1.Literature review:

Chen and Lou (2014) attempted to develop a 4D BIM based system to manage construction quality. The authors used literature review to assist them in developing a dynamic quality control model. The focus of the literature review contribution to the research was to identify how BIM can work in a quality management environment. The result was a quality control template which is to be used during work inspections.

Han, et al. (2013) set out to create a system dynamics model with the objective of assessing of what impact do design errors have on construction projects. Literature review helped in creating a schematic model that identifies the design errors' dynamics. Thereafter, literature review is again utilized to further explain these dynamics assisting in the creation of a system dynamics model. The benefit of the model was to help construction managers estimate more accurately the duration of each construction task. Furthermore, it allows the manager to estimate recovery duration due to these errors. However, the model doesn't propose any prevention or mitigation strategies. The model was implemented in a university model to test its applicability and alignment to its objective.

Yap, et al. (2016) utilized literature review to identify gaps in the research field with regards to managing design changes in the construction industry, refer Figure 13. Thereafter, literature review was further utilized to create a conceptual model which was done in two phases, the first phase included the factors that were deemed causal to design changes. The second phase attempted to expand on the framework to include rework, decision making and communication (refer Figure 13).

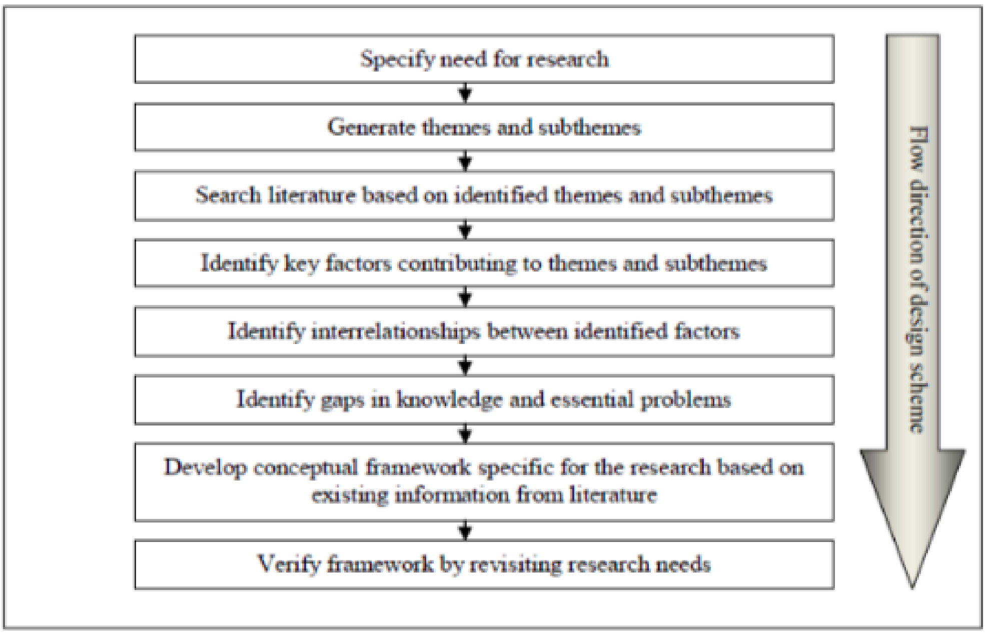


*Figure 13: Flow chart for conceptual model design utilized by (Yap, et al., 2016) who adopted it from (Bhattacharya, et al., 2013)*

Love, et al. (2004) employed literature review to design a survey to analyze the impact of project management influences over rework costs. The results of the survey were then utilized to create a conceptual procurement model (refer Figure 14) which was intended to reduce rework.

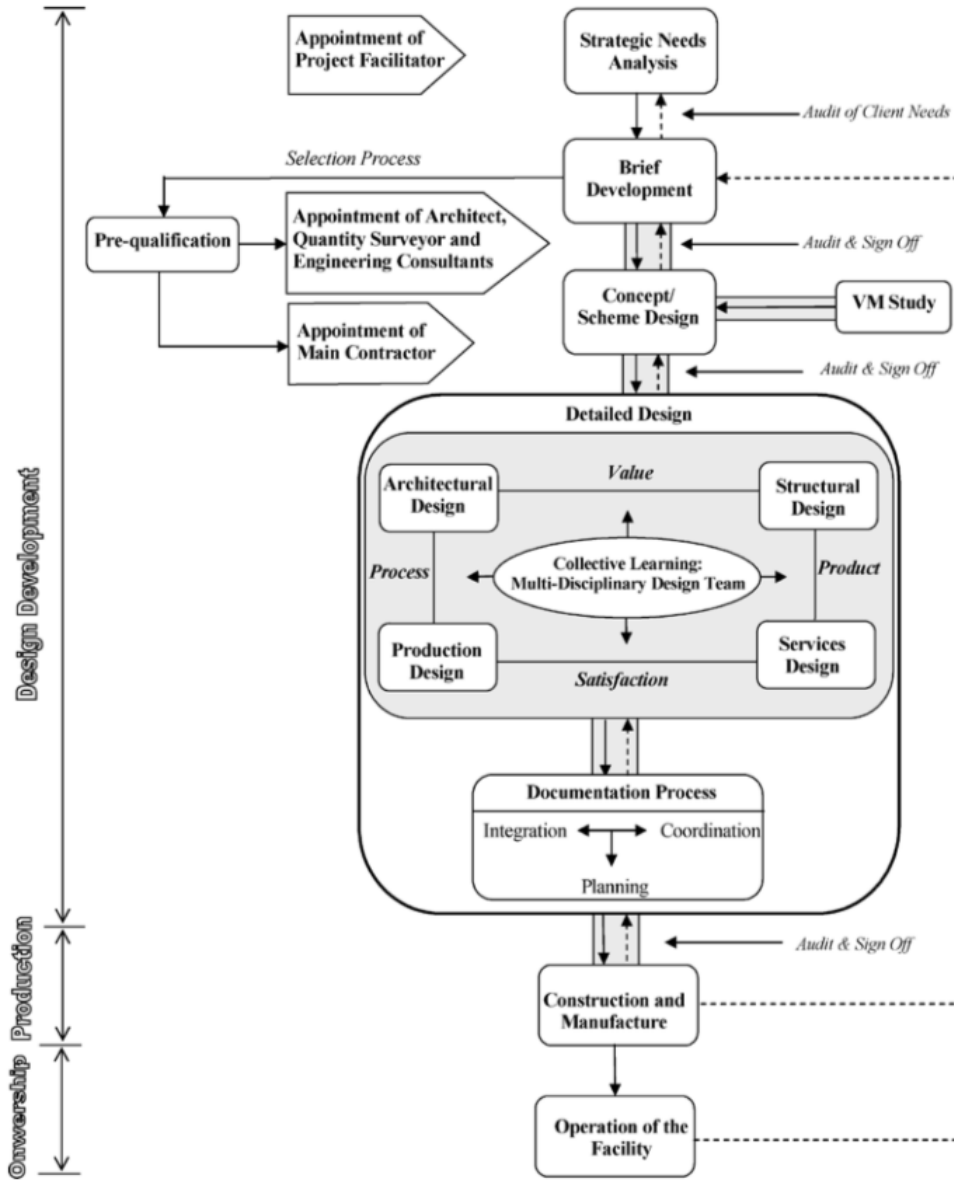


*Figure 14: Procurement model to reduce rework developed by (Love, et al., 2004)*

Mohamad, et al. (2012) attempted to identify methodologies of assessing structural design changes highlighting their sources, causes and impacts. Furthermore, the study sets out to create corrective and preventive actions to minimize design changes. The authors needed a background on design changes in residential reinforced concrete buildings in terms of their sources and causes. This extended to studying the reaction of the management of each case to the changes. The Authors implemented literature review to satisfy these requirements.

Rocha, et al. (2012) utilized literature review in the core of their research as they attempted to study two Ph.D. investigations showcasing how “design science research (DSR)” can be utilized by lean construction research. The outcome of the research provided insights on the DSR that have not been highlighted in previous literature as well as provided a clearer understanding of the DSR cycles. Literature has indicated that there is a single cycle in DSR. However, the two investigations indicate at least two cycles, internal testing and external testing.

Literature review selection as a method of research has proven to be a cost-effective solution for conducting research. Furthermore, it illustrates the vast work conducted by other researchers in a way that is similar to conducting the actual researches. This along with ease of access to this body of knowledge whether within a physical library or via online sources such as Research Gate, which have made literature review a very important tool for researchers. Therefore, allowing it to contribute to researches in a variety of ways such as the identification of a research gap, the structuring of a research, the selection of a research methodology, the design of a research methodology and becoming the main research methodology in some researches. Furthermore, it can be utilized as bases for scope to grow further as in the adaptation of previous works and enlarging their scope. Therefore, Okoli (2015) segregates literature review into three types, the first is known as “The Theoretical Background” which basically sets the context for the research question in a journal article. The second type is known as “Thesis Literature Review” which is basically the literature review chapter in a graduate thesis. The last type is known as “The Stand-alone Literature Review” which is basically a journal long article that only evaluates previous research work and does not rely on the collection and the processing of primary data.

This reliance on previous work does come with certain disadvantages, such as being dependent on the quality of the researches done previously in which the lacking of the same can impose quality risks on the current research. For example, biased previous research will render the current research equally biased due to the reliance of the current research on the previous one. The same goes for inaccuracy in conducting research and poor description of the research conditions and limits.

Furthermore, Researchers employing literature review can be biased themselves as to the selection of references that are in line with what they think or in line of what they are trying to prove. This can be inferior to what is correct.

### 3.1.2. Survey:

Love, et al. (2004) developed a survey to examine project management's influence on rework reduction in construction. Feedback requested had to do with rework cost estimate (direct and indirect). The survey also provided proposed factors for inducing rework and requested respondents to rate their agreement with each factor. Furthermore, respondents were allowed to add a statement of why rework was induced as per their experience. The authors conducted a pilot survey with 30 companies to test the suitability, clarity and response rate. Furthermore, the participants were requested to give feedback to the survey structure. Twenty five responses for the pilot survey were received and provided positive feedback for the survey structure to proceed. The feedback from the survey formed the bases to the creation of the conceptual procurement model created by the authors (refer Figure 14) to help reduce rework in construction.

Aiyetan and Das (2015) issued surveys as part of their research to identify causes of rework (structural) in construction as well as attempt to identify intervention strategies to prevent rework from occurring. The result of the survey aided in the establishment of causal relationships between rework related parameters, these parameters eventually aided in the creation of a conceptual system dynamics models for client causes, contractor causes and design causes. Thereafter, the synthesization of these three models helped create a combined model which includes preventive actions to reduce rework.

Al-Aomar (2012) research aimed at analyzing and identifying the various forms of waste in construction. Furthermore, the author set to establish a lean construction frame work that can be utilized to identify cost, quality and schedule implications of lean construction practices. The survey methodology was utilized to establish an understanding of the lean construction strategies implemented in Abu Dhabi, UAE and its performance measures. Furthermore, the survey also included a proposed frame work to reduce waste that was offered to the survey participants to provide feedback against. Moreover, the survey requested feedback on obstacles preventing the implementation of such strategies.

Survey as a research strategy has the capacity of providing a significant representation of the population. Furthermore, due to the fact that the surveys are usually conducted without the presence of the author, the responses are usually in a reaction to the written question format and content rather than the explanation of the author which ensures consistency of responses.

Moreover, surveys are considered as a cost-effective research strategy as researchers are usually opting for online survey platforms such as surveymonkey.com. These platforms usually offer free access and survey creation facility which can be accessed be any participant with a link to the survey. However, there are still the manual (surveys sent via fax) or semi-manual (surveys sent individually be email) type of surveys which can be more “labor-intensive” approaches to conducting a research. The survey methodology can be combined with a supporting methodology to reduce the impact of such disadvantages.

There are certain disadvantages for utilizing the survey as a research methodology. Misinterpretation of a question is one of the common issues of a survey as any ambiguity in the questions can have a significant impact on the survey’s results. Furthermore, depending on the nature of the research, some respondents may be hesitant to respond due to the fear of being monitored. This may impact the result of the survey.

### 3.1.3. Case study:

Chen and Lou (2014) adopted a case study methodology to illustrate the dynamic quality control model which basically consisted of a framework of implementing 4D BIM and quality management tool. The authors obtained the quality control template and the CAD information from the case study project which formed the basis of the quality management BIM model. Furthermore, the case study project was utilized to test and validate the proposed quality management strategy as well. The same was followed by Han, et al. (2013) who tested their proposed system dynamics model of determining the impact of design errors in a university construction project.

Tribelsky and Sacks (2011) utilized case study to obtain their information of their research concerning the extents of information flow interruptions and how that impacted the design outcomes. The authors selected projects that were similar in nature where they analyzed the information flow during detailed design stage. The information obtained from the case study project included design archives, information transfer logs from the project extranet platform and through attending coordination meetings.

The Case study research methodology can be categorized into three main types, exploratory, descriptive and explanatory. Exploratory case study methodology is usually implemented when the outcome of an interference with a certain context is vague and hard to be anticipated, especially if the context is complicated. Descriptive case studies are implemented when the author intends to describe the phenomena of interest in a real-life scenario. Explanatory case studies are implemented when the author intends to solve a problem or answer a question which has to do with existing and predefined conditions of a real-life scenario. It usually includes the implementation of a strategy or a system to validate its performance against predefined objectives.

Furthermore, Case studies can be implemented as multiple case studies within one research or a single case study within one research. The benefit of having multiple case studies within the research is that it allows the author to compare and contrast against the outcome of each case study. This will aid in the delivery of a solution that has been tested in multiple scenarios which makes its impact more predictable.

The advantage of utilizing a case study approach is that it gives the author the liberty to explore different "sub scenarios" within the context of the case study. Furthermore, it provides the author with real life experience for analysis and interaction.

The disadvantage of utilizing a case study is mainly the challenge that faces the author in the quest of finding an appropriate and suitable case study for the topic of interest. Furthermore, case study requires a significant time investment from the author as it includes the analysis of the existing real life scenario, identify how to integrate the proposed "product" into this scenario and how to pick up the results of this integration to be reported as results.
Moreover, the nature of a case study approach includes the translation of a real-life scenario into research writing which can be influenced by how the scenario is being perceived or how the researcher wants to translate it making the method subjective to bias by the author.

### 3.1.4. Interviews:

Tribelsky and Sacks (2011) employed interviews as part of their research to identify the impact of interruptions to information flow and how that can impact the design outcomes of the project. The authors conducted 13 interviews with representatives of the selected case studies to receive feedback on the design quality of each of the projects. This aided the authors in determining the correlation between quality of design and design interruptions.

Aiyetan and Das (2015) created a conceptual system dynamics model of identifying structural rework causes in construction and develop strategies that would help reduce rework. This model was explained to construction professionals during interviews in order to validate its feasibility and its fulfilment to its objectives.

Furthermore, interviews were adopted by Ben-Alon & Sacks (2017) in their research to create a simulation model (agent based) that would study the production control policies in a construction project. The interviews provided insights of construction information and work processes as well as behavioral parameters of construction parties which aided in the creation of the simulation model.

Mohamad, et al. (2012) utilized interviews to collect opinions from construction professionals (clients, consultants and contractors) with regards to the extent of the impact of structural design changes on construction projects. Eleven semi-closed questions were included in the interview for four construction professionals. The data obtained from the interviews indicate that construction projects usually never end without changes in design. Other results include the identification of the client as the main source of changes and that lack of coordination can result in significant buildability issues.

The main advantage of utilizing interviews as a research methodology is that interview questions can be probed and clarified with additional follow up questions increasing effectivity of responses. Furthermore, they have the flexibility of being conducted in any time or locations. There are many types of interviews (Kajornboon, 2005), such as:

- Structured interviews
- Semi structured interviews
- Unstructured interviews
- Non-directive interview

Structured interviews are characterized by having the same question provided to all the interviewees. The limitation of this method is that probing can become challenging in such context should interviewees misunderstood the question or weren’t provided with sufficient data to reply to the question. However, it still provides the author with complete control over the flow of the interview.
Semi structured interviews are characterized by being less strict in terms of their flow. The author while utilizing this type of interviews is usually trying to obtain the further feedback that is provoked by the interview questions. Furthermore, the format of the interview allows the author to change the sequence of question as he

sees appropriate during the interview. Moreover, the author may even ask further questions that weren't included originally in the interview's structure.
The main advantage of this type is that it allows the author to probe for questions to ensure the interviewee fully understand the question. Whereas the disadvantage of this type is that experience in conducting interviews plays an important role in such type as the interviewer may miss to probe a question which may impact the response's accuracy.

Unstructured interviews are characterized by being more flexible than the two previously discussed methods. It allows the interviewee to engage freely in the topic of the interview in the absence of a structure for the interview to follow.
The advantage of this type is that there are no constraints attached to the questions. Furthermore, it allows the author to understand any motives for the responses and for the interviewees to elaborate more on questions and to share their experiences. The disadvantage of this type similarly to the previous type is that it requires experience in conducting interviews. This is since there is no structure for the interview therefore the author must steer through the topic and ask the right questions. Furthermore, it gives the opportunity for the interviewee to talk about topics that may not be relevant to the research topic therefore making it more difficult to analyze outcomes.

A non-directive interview is, unlike the structured and semi-structured interview, characterized by having no theme or topic to be pursued by the author and there are no predetermined questions to be asked. The interview is orchestrated by the interviewee unintentionally and not the interviewer. The interviewer's role in this context has only to do with clarifying unclear statements by the interviewee.
The advantage of this type is that it allows the interviewees to uncover what they really think or feel the problem is as well as why they believe that. It sheds light on not only the problem but on how the problem, its causes and it solutions are perceived or thought about. Providing the author with insights that may not be accessible in a more restricted interview type.
The disadvantage however lies in the same cause of why this interview type is unique. The freedom provided to the interviewees takes away the freedom from the

interviewer which would sometimes prevent him from steering the interview in a beneficial direction to the topic in interest. Furthermore, analyzing the outcomes of such interview can be problematic due to the fluid nature of this type.

### 3.1.5. Design Science Research:

Design science research (DSR) is a methodology that is adopted when the research needs to answer a certain question or solve a particular problem (Offermann, et al., 2009). This process takes place through iterations of proposals until the objectives of the research is achieved creating what is known as The Artefact (Peffers, et al., 2006).

Ben-Alon and Sacks (2017) utilized DSR as a research methodology in their attempt to create a simulation model which is to analyze the production controls in a construction project. Furthermore, the study aimed at understanding the impact of decision maker's behavior on site progress. The authors created a pilot simulation model to test its applicability via utilizing information obtained through field observations and interviews. This helped them create the final "Artefact" which was then validated against predictable scenarios to ensure viability.

The main advantage of DSR lies in its core of problem solving through iterations, the solution proposed never seizes to evolve through different testing iterations unless it is objectives are met. However, this can also be its main disadvantage as multiple iterations can take significant amount of time which the research time frame may not tolerate. Furthermore, DSR can't exist in isolation from other research methodologies (one can see DSR depends on other research methodologies for it to take place). This is due to the requirement of this method of identifying a problem, validating its relevance, propose a solution, test the solution, modify the solution as per the obtained results then validate the alignment of the solution with the objectives of the research. Identifying a problem would require the employment of literature review, a survey, an interview or a case study. The same applies to a proposed solution and its validation.

### 3.1.6. Observations:

Ben-Alon and Sacks (2017) utilized observations as part of their attempt to simulate construction crews on site, it allowed the authors to identify influences that had to do with how decision-makers act on site as well as understand how work progresses on site.

Chen and Lou (2014) utilized the same methodology in order to collect site related data that helped them create their proposed BIM Based dynamic quality control model.

The main advantage of this method is the direct accessibility of the researcher to the state of context for an area of interest. The researcher can observe people's actions and behaviors, physical and non-physical changes, contextual influences, sequences, even can be part of the experience should there be any participation in the activities of interest.

Disadvantages include changes in behaviors of the observed as soon as they know they are being watched resulting in an inaccurate observation. Furthermore, observer's bias can take place as to the explanation of the cause of a situation among other possible causes. Moreover, processing data for observations for a large number of participants may be tedious and can contain ambiguity.

## 3.2. Selected methods for this study:

Researches discussed previously have utilized different research strategies depending on the area of interest and accessibility of means of such research methods. Therefore, and in consideration of the object under investigation of this study and the available means to the author of this research, the selected methods for this study are Survey, Case study and interview. Literature review will be employed to set the theoretical background of the research. The chosen methods will counterpart one another in achieving the objectives of this research.

These methods will also ensure relevance to the UAE market as the three of them will be done with UAE based construction professionals and UAE based construction project. Furthermore, utilizing more than one method can both highlight discrepancy in output should there be a flaw in the execution of one of the methods or reinforce the findings should the result yielded are matching. This will help overcome each method's disadvantages.

### 3.2.1. Literature review:

This research will use literature review as a mean to gather previous problems highlighted by other researchers. Furthermore, it will utilize their proposed solutions and potential answers to the objectives of this research which shall be considered in the final conclusion of this research. This will also assist the researcher in identifying gaps in previous researches that needs to be filled. Aiding in the improvement of the endeavor of the current research since previous researches will highlight their limitations which will equip the author better to avoid them.

The literature review will highlight the causes of rework in construction and will help the author classify them origin wise. Knowing the rework factors caused by the contractor will aid the author in proposing solutions to tackle them as part of this research scope.

The time frame of the researches adopted in this research as well as their nature (journal articles, books, reports, websites, etc) will be highlighted in the appendices of this research.

### 3.2.2. Survey:

Technology have made this methodology easily distributable as well as easily accessible. The survey questions will be designed around the topic of the research. These questions will be inspired from the literature review as the latter will identify problems as well as solutions which both the survey will try to reinforce. Details of the survey will be discussed further in chapter 4.

### 3.2.3. Case study:

As discussed previously, case study methodology was utilized for observation as well as evaluation and validation. As part of this research, case study method will be utilized for observational purposes only. The aim of this method is to obtain information with regards to some of the techniques that are currently implemented to reduce rework in construction sites. The techniques will be explained and criticized in terms of effectiveness aiding the researcher to conclude proposal for improvement. The author will ensure the selection of a project type that is common enough in the UAE to ensure applicability and generalizability of observations and conclusions. Details of the case study will be discussed further in chapter 5.

### 3.2.4. Interviews:

This research will implement a semi-structured interview to allow for a balanced structure flow of dialogue while allowing for certain flexibility in expanding on answers by the interviewees. The interviewees will be given the opportunity to criticize the solutions proposed to the problems identified in the literature review and the survey. Their feedback will constitute the conclusion of this research. Details of the case study will be discussed further in chapter 7.

# Chapter 4: Case study analysis

This chapter will discuss the current knowledge management procedures and protocols implemented in the selected case study and will attempt to highlight its benefits, shortcomings and causation of good or poor performance through direct observations by the author.

## 4.1. Case study Selection:

The methodology of case study analysis as a data collection instrument was adopted as it provides real life scenarios with identifiable causation and visible results and impacts. This is since processes of any particular activity can be revealed and understood through direct observations. The quality of the observations is enhanced through involvement and participation in the said activities by the author, which provides clearer insights on different procedures and processes. Therefore, the author decided to adopt a case where he is currently working as an architect to leverage the data available in that environment and the ease in which they are obtained and interpreted. In addition, it serves as to obtain a sense of a real-world scenario with real-world conditions, applications and environment where the author can present and discuss his experience in that project. The case study is a mixed-use high rise building in Dubai, UAE with 56 floors and 2 basements, it includes residential units and retail units. The client is a private developer based in UAE. The contractor is a medium size organization with limited experience in vertical construction (towers). The project type is very common in UAE (refer Figure 15).

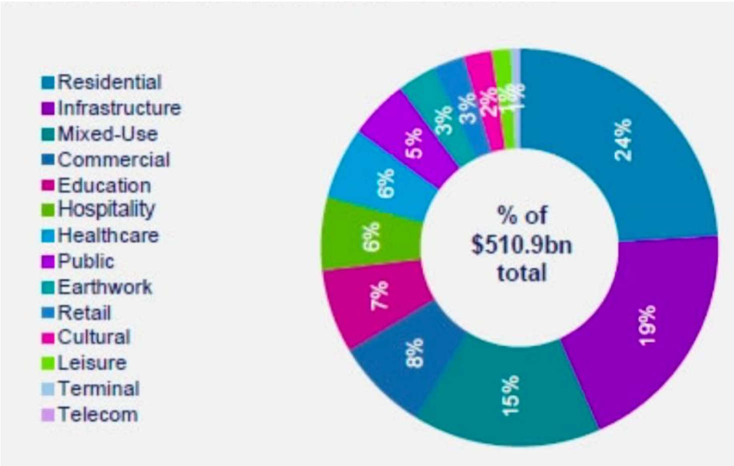


*Figure 15 : The GCC construction project market - Contracts awards by sector, 2006-2013 (MEED, 2015)*

The project nature in being vertical (high-rise with limited foot print) posed significant pressure on the delivery program due to accessibility provisions for both labor forces and materials. Furthermore, the impact of this issue was increased due to the perception of project as a small footprint building which resulted in limited workforce and staff presence. Managing knowledge in such dynamic and fast-paced environment was another reason why the author chose this project as a case study.

The project followed what is known as the “critical path” system for activities and construction planning. It basically allows team members along with management individuals to identify when the starting date of a certain activity is and when it should end. Furthermore, it allows the operations and the management teams to track progress throughout the entire project and exhibit the status of each area within the project. The project also utilized cloud based document management system known as ACONEX where all submittals (shop drawings, material submittals, method statements, prequalification, etc.) were initiated, processed and archived which helped in the information management process of the project.

The following section will go more in depth with the knowledge management/rework reduction strategies implemented in the case study in order to manage knowledge and reduce rework.

## 4.2. Implemented strategies for knowledge management / rework reduction in the case study:

This section will discuss a group of strategies and techniques that have been implemented in the case study to maintain a standard level of quality. They vary in their performance and impact on quality levels. Some of the proposed strategies are considered proactive as they attempt to avoid nonconformance. These strategies include the appointment of dedicated quality control staff, application of benchmarking, construction planning and the application of area access record system. Other strategies are considered reactive to prevent an already identified error and attempt to fix such as on site design.

There are many factors that contribute to the success of any of these factors including motivation, commitment, awareness, etc. However, these factors will not be addressed in this section. Each strategy will be introduced and its benefits will be highlighted. Furthermore, causes which necessitates the application of such strategies will be highlighted. The main implemented strategies are:

### 4.2.1. Employment of specialized and dedicated quality control team:

The role of quality control (QA/QC) team in the project have aided significantly the level of quality in the project. This is since it is the responsibility of this team ultimately to deliver a well-rounded product to the client ensuring up to standard and satisfactory project execution. The roles of the QA/QC included the following:

- Review and approve work execution method statements to ensure the relevant guidelines within the project information and relevant standards are included and followed.
- Review and approve material submittals to ensure alignment with the project's specifications.
- Inspect the condition of the materials delivered to the project's site in its suitability for its intended purpose.
- Inspect the completed works of each activity to ensure it has been executed in accordance to the intended design, the project specifications and relevant standards.
- Issue non-conformance reports to wrongly carried out works on site which are not in accordance with the project's information.
- Track and monitor that the sequence of construction is being carried out to encourage optimum efficiency.

Despite the level of efficiency such team operates with, it remains limited in effect should not their role and input be authoritative. This is since nonconformance can be hidden by other trades such as poor installation of MEP equipment above the ceiling level which can be hidden by the ceiling for example. Yet if the QA/QC authority is respected, the MEP equipment will be inspected properly and ceiling work will not commence unless clearance is provided from the QA/QC team. This authority can only be enforced and stabilized with the support of senior management who should be able to see the benefit of having such team on board.

The absence of such support renders their role merely cosmetic and would have little to no impact on the overall construction process.

## 4.2.2.Implementation of benchmarking system:

The idea of having a benchmark in the project has the advantage of achieving many objectives such as managing client's expectations, understanding the requirements to design, procure, deliver and install materials, highlighting any problems in that process which may impact planning, give a realistic estimate to the required resources in terms of materials and labor force and provide a reference sample for the rest of the project assisting in decision making process in other areas or cases.

The downside of implementing such strategy is that it provides a completed physical display of the final product for the client where it can be evaluated, this usually results in design changes for items or issues that weren't picked up in the design process by the consultant/client. Furthermore, it provides a demonstration of all items of which some may be envisioned to be satisfactory on paper but deemed not satisfactory after being evaluated physically.

The changes that follow the benchmark inspection are usually pushed back to the contractor, the consultant/client usually reject the first inspection request issued by the contractor with comments and hand sketches putting pressure on the contractor to adopt these changes in the shop drawing process to obtain approval. This usually happens during the shop drawing preparation stage carried out by the contractor's technical team where the design and submission of shop drawings and other information has already progressed and a new area has been commenced by the detailing teams. Aside from time spent evaluating these requested changes and the case building required to fight off these changes by the contractor which is usually done by the contractor's technical teams, these changes will then force them to come back and revisit the benchmark zone to revise the design once these changes are accepted. Furthermore, this will force the team to adopt relevant comments in zones other than the benchmark area which usually has a significant impact if it's a project with similar usage between different zones such as a residential tower.

This would result in a significant downstream feedback of information which usually causes a sort of a backlog as the same team is working on revising the design while still trying to move forward with the detailing of the next zones. Such sudden influx of load on the technical teams can have a significant impact on the project information delivery plan and is rarely anticipated in the planning of construction or in human resources requirements.

The other issue with the benchmarking system is that it gives liberty to the operation teams within the contractor to propose solutions for undeveloped designs. This takes place by building a zone as a mock up to demonstrate the same to the consultant / client then upstream the design to the technical teams to maintain a paper record. This may work very well in the case of technically aware and experienced operations members but may create confusion should the design fail to achieve certain project parameters, resulting with an approved mock up for a design that doesn't work in most cases. Such scenario would result in scrapping the installed mock up at the least. Furthermore, it will consume additional effort by the technical team attempting to validate what has been done on site already to the consultant/client in order not to cost the project.

What needs to be noted is that benchmarking remains a beneficial tool to enhance design, procurement, planning, installation, overall quality and client satisfaction in construction, provided that awareness of the above-mentioned disadvantages is present and their impact is thought/taken care of.

### 4.2.3. Implementation of the line-of-balance (LOB) system:

As discussed earlier in this chapter, the line-of-balance (LOB) system is a planning process that helps construction professionals in planning their resources and monitor the construction progress in a project that have repetitive activities, an example of the same in Figure16.

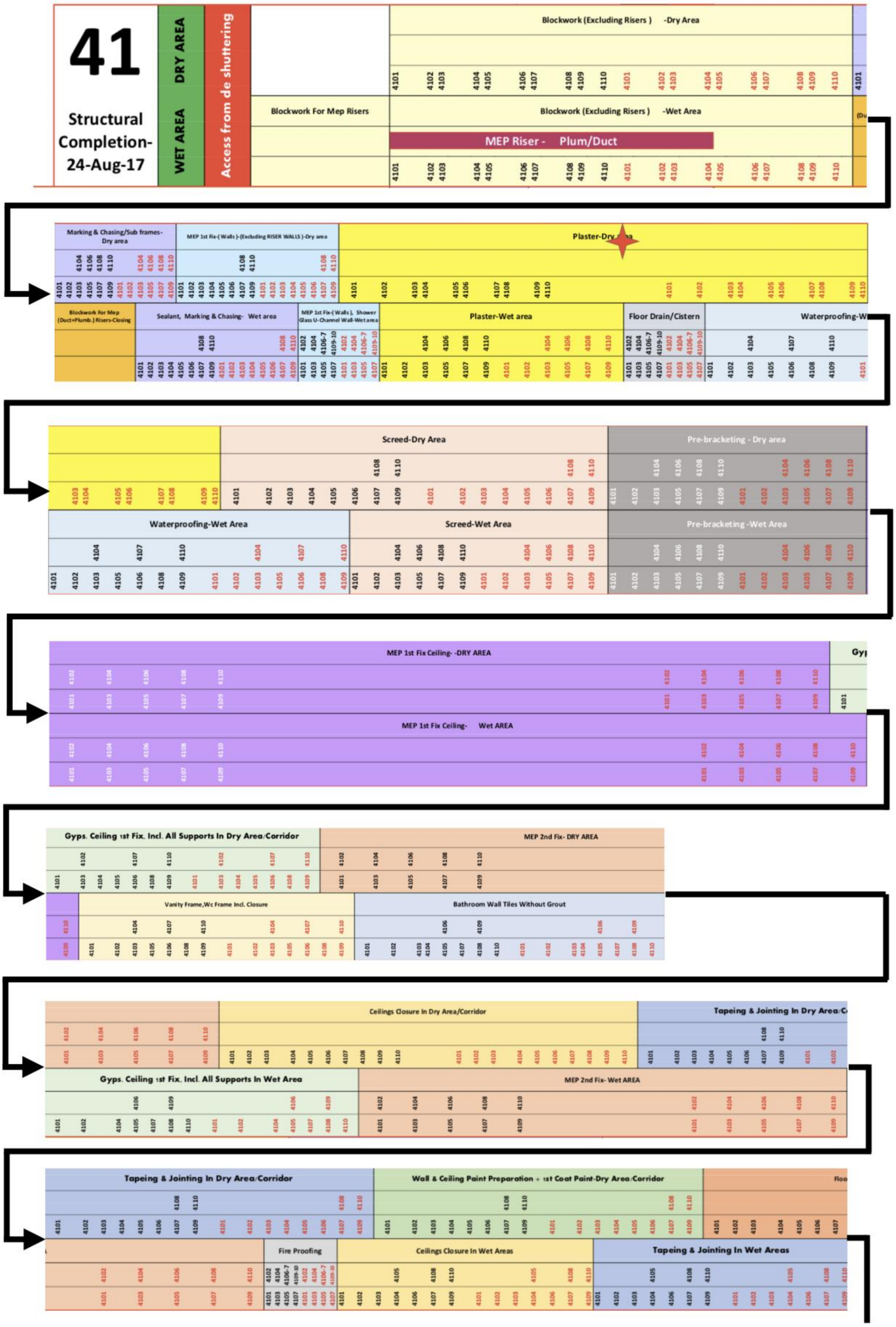


*Figure16: An example of a pictorial LOB program (part 1)(Author)*

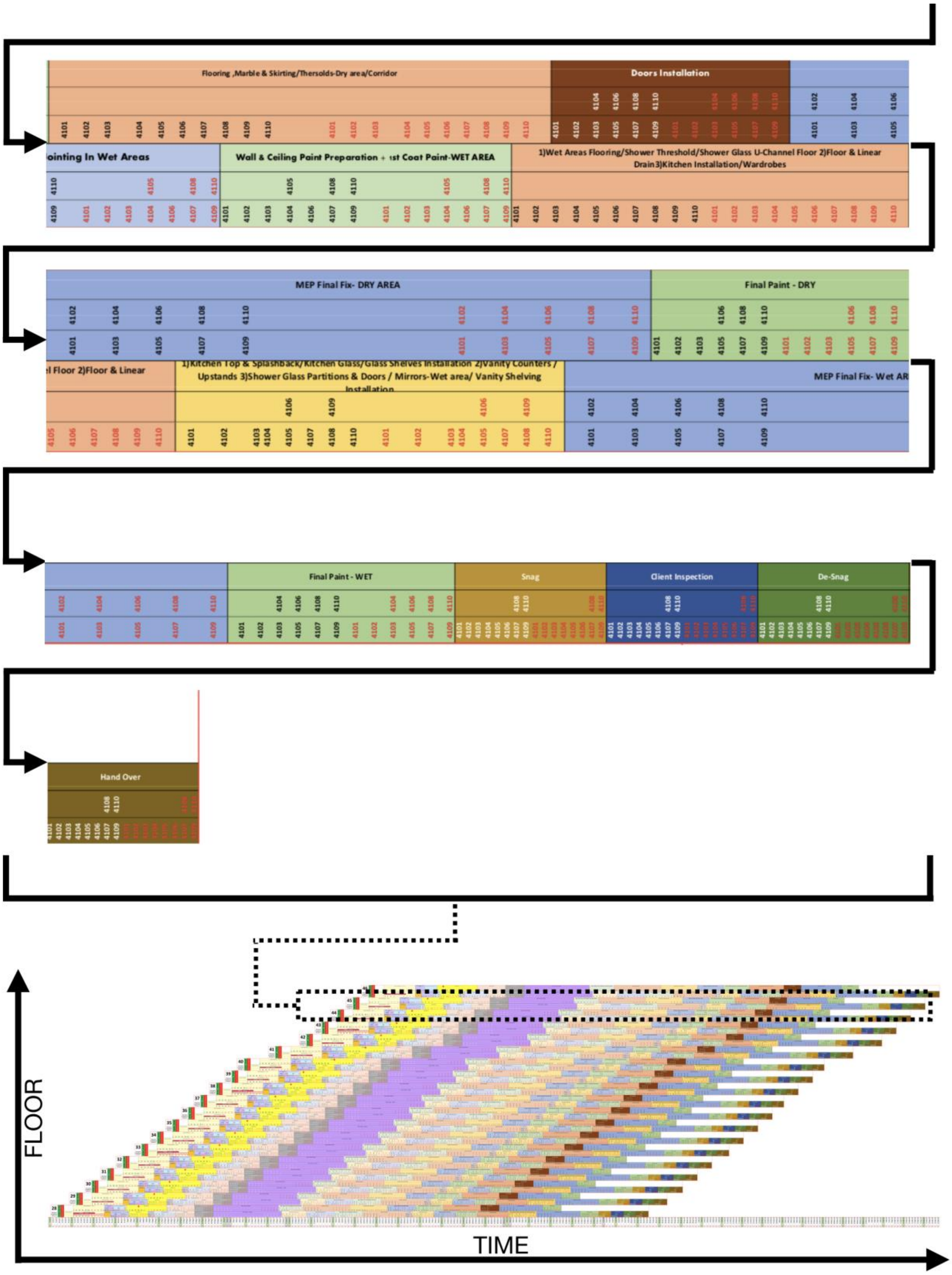


*Figure 16: An example of a pictorial LOB program (part2) (Author)*

This strategy usually employs what is known as the "Critical Path" which is basically identifying the longest chain (in duration) of dependent construction activities then plan the shorter chains and independent activities within that duration (refer Figure 17).

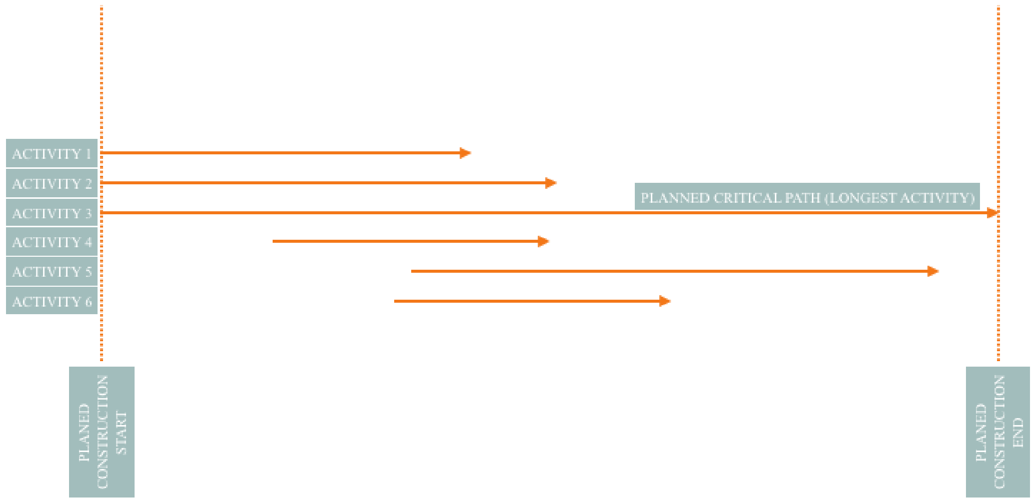


*Figure 17: A demonstration of the critical path (Author)*

The benefit of such system is that it helps both the technical and the operations teams in planning their activities. This is because they know when each activity should start on site with the help of pre-defined procedures and protocols and their known durations.

An example would be the casting of a concrete slab in a zone, the date of casting is identified in the LOB plan therefore the materials needs to be ordered before this date. For the materials to be ordered, the design by the technical teams should be concluded and approved by the consultant beforehand. This is because there is a lead time for material delivery (rebar manufacturing and cut to size along with concrete batching).

Sometimes the design by the technical team happens in two stages such as in concrete design, the first stage consists of finalizing the sizing of the structural elements and the locations of supports and openings which when approved, the second stage commences where the rebar gets designed as per the configuration of the structural elements which also requires consultant's approvals. This is usually predefined in what is known as "information release schedule" which is basically a representation of the duration to prepare for an activity before it starts on site (refer

Figure 18). All of these activities needs to happen in a structured sequence before the site activity commences therefore all teams can plan their deliverables based on the site activity dates governed by the LOB.

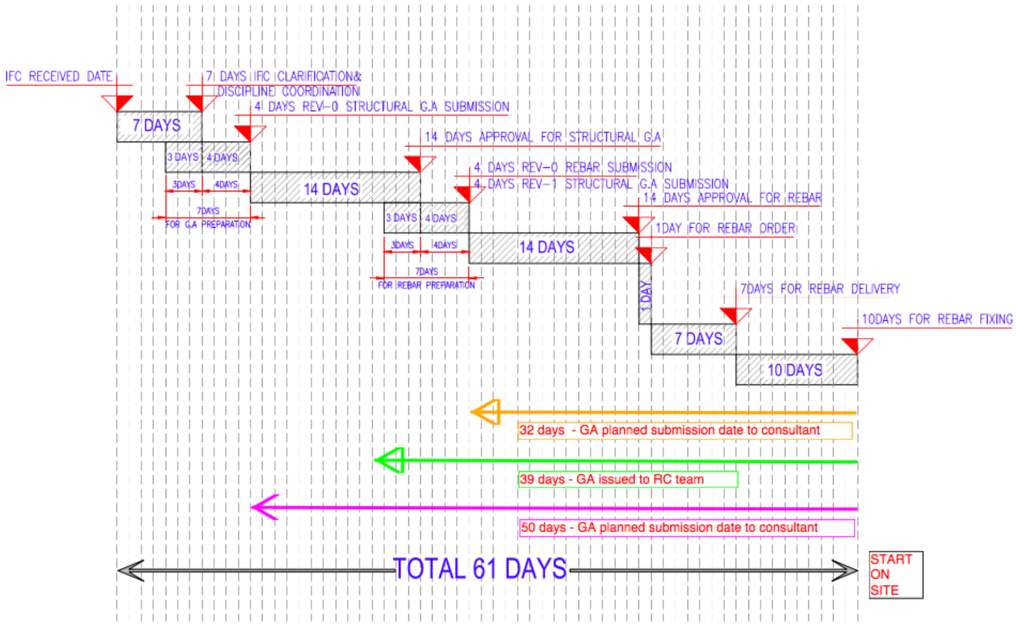


*Figure 18 : Demonstration of an IRS schedule (Author)*

Occasionally, the chain of activities that governs the critical path changes as the driving activity of the critical path shifts due to the delay of the start of a certain activity on site. This will result in pushing its conclusion beyond the initial planned construction end and sometimes even beyond the last planned critical path activity (refer Figure 19).

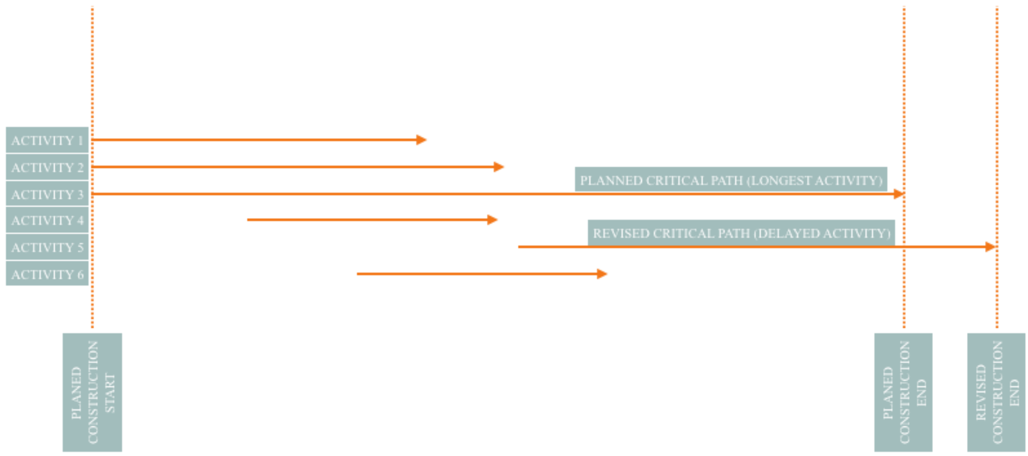


*Figure 19: A demonstration of a revised critical path due to the delay of commencement of a secondary activity (Author)*

This usually will result in the attempt by the construction management of the project to try to squeeze and reduce that duration to bring it back to the original completion date (refer Figure 20). This is because this date has been already agreed with the client as the project delivery and any delay beyond that date may impose financial penalties on the contractor.

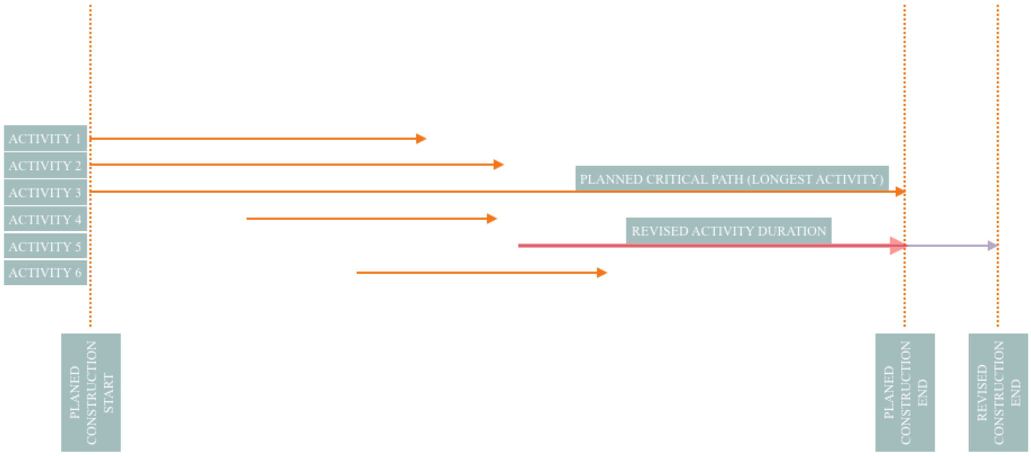


*Figure 20: A demonstration of a revised activity duration to match initially planned project delivery date (Author)*

In consequence, this would result in an impact on some if not all of the processes within this activity such as design, approval, procurement, delivery and installation. Furthermore, it may potentially impact other activities as more work needs to be done with the same resources (refer Figure 21) which may ultimately still push the finish date beyond the planned date.

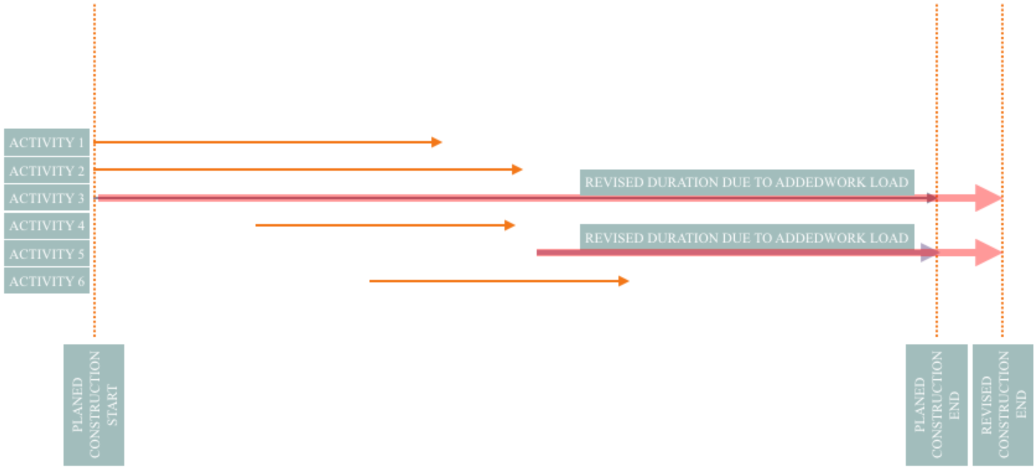


*Figure 21: A demonstration of the impact of reducing the duration of an activity to align it with the project's critical path (Author)*

The strategy of LOB is used to plan resources as discussed; this includes the planning for resources requirements of the technical teams along with the operations teams which may be a significant help to determine these requirements early on in the project. However, as discussed early on in this section, it doesn't factor in sudden influx requirements due to construction program slippage or like what was discussed in the previous section of this chapter for example. Such conditions would cause revisions to such programs which by default will force change on all the dependent programs. Leading to pressuring the IRS process to become shorter in order to maintain the targeted date of the critical path. Such scenarios would probably have an impact on the quality of the generated information in terms of relevance and accuracy potentially causing rework on site.

Furthermore, the accuracy of such construction programs plays a significant rule on the pressure exerted on the design process carried out by the technical teams of a project. The planner should have sufficient knowledge of the duration of various construction activities along with sufficient familiarity with the design and the requirements of a project. This is considered crucial as missing to factor in a process within an activity would cause all other processes within this activity to shrink to maintain original agreed on delivery date. The other alternative would be to increase the duration of the activity itself as the late identified process needs to take place forcing a domino effect on potentially all the other activities in the project.

### 4.2.4. Implementation of Area Access Record (AAR) system:

Construction activities taking place on a construction site are governed by a predefined sequence which is logically structured to prevent abortive work due to limited accessibility, potential damage by a different trade, etc. An example would be the installation of false ceiling in a certain area which shouldn't start until the MEP equipment above the ceiling level are installed, inspected and tested. Failure to achieve that would cause the ceiling installer to do the work twice increasing rework and waste. Furthermore, this sequence is fed into the LOB program of the project for accuracy of the program and to monitor progress on site to optimally detect any slippage.

The AAR system tracks the application of the predefined sequence by maintaining a record of who accessed a certain zone within the project to action an activity along with when this activity started, finished and inspected. This information is up streamed to the planner to assess the progress on site in comparison to the planned progress. Then this information is up streamed to the construction management to be notified of an out-of-sequence or delayed activity if any. This will allow the site management to take preventive or remedial action accordingly.

The AAR system was implemented in the case study by having a physical document per area which moves between different trades as per the predefined sequence. Each trade representative signs off on receiving the physical document and on releasing the same to the QA/QC team authorizing them to inspect the work done. The QA/QC team would again sign it off before returning it to the previous representative in case of inspection rejection to rectify the work or releasing it to the representative of the following trade. The transfer of the document is administrated by a supervisor who ensures the document remains active between different trades, the supervisor regularly updates a log which highlights the status of each zone within the project and notifies relevant parties of the updates. That log is basically the information that would then be up streamed to the planners and the management teams.

The implementation of the system did not continue in the project for a number of reasons, such as the fact that the supervision task was assigned to one of the construction team members as a secondary task besides his daily duties which caused the system to not function promptly, this is due to its low-tech nature and the fact that the supervisor had to meet each representative and QA/QC member to obtain the sign off on the document which was time consuming. Furthermore, the system became an excuse for the different trade representatives not to start their work as the AAR document took a long time before it reached them despite the fact that the zone is ready to receive the next trade team.

The failure of the system resulted in the implementation of a system which circulates clearances to access zones through emails. This system proved to be difficult to track and resulted in a lack of update of the actual status of work on site to both the management and the planners. Furthermore, it created difficulty to track the implementation of the planned work sequence which caused significant amounts of rework to take place in the project. This is because no one was able confidently identify who should work in which zone anymore. Moreover, no one could prevent different teams from revisiting semi-done areas or starting new activities even though previously sequenced activities haven't concluded their work. This resulted in a complete chaos and lack of discipline on site.

Moreover, and due to the loose nature of the new "system", rework causes where not identified nor recorded therefore became incredibly difficult to prevent. Furthermore, the absence of a clear accurate record created a blame game style in progress meetings where different trades blamed each other of holding zones due to uncompleted work which caused the project to slip from its planned program.

This resulted in forcing the planners of the project to devise mitigation programs to catch up with the project's deadline. Such plans essentially affected all trades and was based in most cases on inaccurate base information from site. Furthermore, it placed all teams under pressure to execute works in haste significantly impacting quality.

### 4.2.5. On-site design development:

As discussed in the introduction and the literature review chapters of this research, there are multiple reasons why the issued for construction information is not ready to be used directly on site and that they provide only an outline in which the design has to be developed.

Furthermore, there are certain requirements which has to do with the constructability of certain elements in a project which would require the design to be altered to suit such needs, an example would be the strengthening of certain areas in the structure (increasing thickness and or rebar) to allow tower cranes or hoists to tie into them. Despite this methodology being a common technique for carrying out construction in vertical projects, consultants continue to design the structure to serve its "post construction" role only without attempting to foresee the requirements of construction.  Forcing the contractor to make the adjustments and to usually appoint third parties to validate the new design.

Further to the above, the construction usually commences based on incomplete information as to the nature of project delivery process here in UAE. The developers usually commence to sell units in the event of a residential project to future tenants based on estimated completion date. Therefore, even if there is an absence of complete information, the consultant usually provides limited information just to allow construction to start even though there are no frozen requirements for these areas. This limits the flexibility in decision making when finalizing the overall design. Moreover, it forces the contractor to participate in the design development and decision-making processes under the pressure of the construction management to progress on site. Placing additional load on the contractor's technical teams as not only they have to produce information for construction, but they also have to be part of the creation of the base information of the same which should've been done by the consultant.

The absence of comprehensive design information usually leads to miss-coordination as the contractor can't coordinate elements that are not visible or will be added in the future, this would result in a drastic increase of revised shop drawings as well as request for information documents. All of this will increase in design load on the contractor's technical team which is not only detailing the design of the project but also participating in the design process itself. Such scope increase is usually not allowed for in the allocation of design resources of the project by the contractor. This process caused the case study to resubmit over 2600 drawings in design revisions of little less than 6900 drawings as total submitted shop drawings.

This ranks up to a percentage of 37% of virtual rework alongside with around 590 submittals of request for information (RFI) documents.

Further to the unclear design intent establish by the incomplete, uncoordinated contract documents provided by the consultant, the design development forced the contractor to change certain aspects of the design which deviated from the provided information by the consultant. This has resulted in a series of revised drawings and design development workshops among the client, the consultant and the contractor to agree on the revised design.  Resulting in uncertainty in the provided shop drawing and chaos in the planning process as the planners couldn't freeze activities commencement date as the design of the same was not frozen.

Moreover, due to the urgency of the information delivery to the site to commence construction, the client was forced to issue the information by the consultant to the contractor prior to conducting internal reviews. This led to the presence of design features that we're not satisfactory to the client but were processed and sometimes built by the contractor. This led to issuing over 140 of site instruction to enforce design changes where details provided in the instruction in the form of written data or hand sketches superseded issued for construction documents and information, this caused both physical and virtual rework by the contractor. Furthermore, this has caused the extension of the IRS schedule as client approval on shop drawings based on IFC information and instruction had to be factored into the IRS. Yet further to the discussion in previous sections of this chapter, any addition of a process to an activity will result in program slippage and increase pressure on existing resources impacting negatively on the progress of the project.

As discussed in the previous sections, the case study has adopted multiple processes that were either proactive or reactive to rework causing conditions. Some of these processes seems unavoidable by the contractor such as site based design development due to poor contract documents. Furthermore, the contractor usually absorbs these problems in order to remain in competition during tending. As otherwise, posing additional fees due to poor contract documents can put the contractor at a disadvantage in a saturated market as the UAE's.

However, being mindful of the impacts of the processes discussed in this chapter and attempting to overcome their disadvantages as much as possible can help reduce rework significantly. An example would the automation of the AAR process discussed earlier which will overcome its labor intensive nature, this will help facilitate its implementation in construction projects and enhance its positive impact on rework reduction.

# Chapter 5: Survey design and analysis

This chapter will discuss and analyze the survey which was conducted as part of this study. The survey attempts to emphasize and confirm rework related factors and investigate feedback on proposed techniques and methodologies to help reduce rework in construction site within the contractor's scope.

## 5.1. Survey design and selection:

The selected survey methodology for data collection was E-Survey as it can compile respondents' feedback from different backgrounds with little time and with high level of efficiency. Furthermore, it allows for detailed response should the respondents feel the need to do so.

The survey will commence with clarification on the participants' background. The purpose for that is to ensure that the topic being investigated is addressed from as much relevant variety as possible.

The second section of the survey will serve as a confirmation to the viability of the research topic. This will be achieved in investigating the amount of rework that is being carried out by the participants which will help illustrate if the problem exists or not.

The third section of the survey aimed to rate the factors origins that will cause rework in terms of their impact. There are 5 factors that were identified in the literature review section of this research. Therefore, a five point likert-type scale was utilized to allow the participants to rank the factors. The survey design didn't allow the participants to place two different factor groups in the same rank as part of the survey design.

The fourth section of the survey aimed to identify the importance of each rework inducing factor identified in the literature review chapter. This will help the author focus the solutions package that will be proposed on the most important problems that is leading to rework. Evaluating the importance of each factor will be done using a three point Likert scale in order to identify the feedback of the participants. The three-point scale was utilized to in order to simplify the response in being important, moderate and with no importance. This is since adding more gradient to the scale has no benefit to the required results.

The fifth section of the survey was aimed to rate the importance of the role of certain strategies that can be implemented to reduce rework in construction. These strategies were identified & inspired from the literature review as well as the case study chapters within this research. The feedback on the same will be received in the form of rating which utilizes a three point Likert scale. Only three-point scale was utilized in order to allow the participant to rate if the strategy has high importance, medium importance or no importance in its impact on rework reduction. Furthermore, the decision to proceed with a three-point scale was due to the fact that adding more gradient to the scale has no benefit to the required results.
The sixth section of the survey was aimed to identify the perceived level of BIM implementation in the organizations of the participants. This will help and confirm the viability of BIM related rework solutions within the solutions package to be proposed. Furthermore, it will help provide an insight on the applicability of any proposed BIM related activities since BIM presence is a prerequisite to implement BIM related strategies. The section investigates the perceived level of BIM implementation in being fully implemented, semi implemented and not implemented. Moreover, the cause behind seeking the perceived level of BIM implementation rather than the actual level of BIM implementation in a firm was to simplify the rating process. This is due to the difficulty in carrying out a study by the participants to identify the actual BIM implementation level within their company which is not practical. Furthermore, a perceived level of implementation can give insights on how well the technology is being utilized and not only if the technology is acquired.

The seventh section of the survey was added to identify the perceived causes of the perceived level of implementation of BIM. This was added to help the author understand the mindsets of the stakeholders within construction which would help better shape the solution package to be proposed. The section format allowed the participants to freely input their opinions without any restrictions.

The eighth section of the survey attempted to establish a connection between the type of data being interchanged with regards to the stakeholders' level of BIM implementation to the amount of rework. Participants will be asked their opinion regarding the exchange of information between companies with different level of

BIM implementation and if that would induce rework. Participants will be given the options of voting positively or negatively to this question.

The ninth sections will basically request the participants to suggest any other strategies that would help reduce rework in construction.

The questions of the survey were designed to help achieve the following:

- Establish a sense of the number of tasks that is influenced by rework which is carried out by construction related individuals in their daily routines.
- Confirm or nullify the rework causes which were identified in the literature review and through direct observation by the author.
- Obtain feedback on certain proposed solutions which may help in alleviating rework under the contractor's scope.
- Identify the drivers behind the level of BIM implementation in the participants' firms and whether rework may be induced due to the interface between entities with different level of BIM implementation.
- Communicate and highlight additional causes and potential solutions for rework.

The survey was piloted with 5 participants to highlight any issues with its presentation, flow and clarity. The feedback returned positive which encouraged the distribution to a larger base of potential participants. It is to be noted that the survey was emailed explicitly to potential participants to ensure the quality of the collected data being from relevant backgrounds to the construction sector. The survey can be found in Appendix A attached to this research.

## 5.2. Sample time frame:

The survey was first designed on the online platform surveymonkey, the survey was then circulated to 5 selected participants from different backgrounds to obtain feedback with a duration of 1 week. No modifications to the survey took place as the feedback from the initial participants was positive. Which encouraged the author to distribute the survey to further participants. The survey then was open for the period of 2 weeks.

## 5.3. Who received the survey:

The author will utilize the "purposive sampling" methodology with maximum variation in selecting the participants. The methodology is defined as the meticulous selection of participants due to their characteristics (knowledge, experience, etc), availability and willingness to participate in the survey. The selection of the sample as per this method is not random and there are no requirements to a certain number of participants (Etikan, et al., 2016). The characteristics of the participants would include professionals who the author have worked with and were identified by the author as information rich sources. This segment is coming from different backgrounds that are related to the construction industry including developers, consultants and contractors which achieves the maximum variation requirements of the sampling process. This segment will be emailed the survey link with the request to conduct the same. The breakdown of the participants' backgrounds will be provided within this chapter (refer ). Thirty five potential participants were identified and contacted among which thirty three participants took the survey. Furthermore, the experience of the participants ranged between 4-15 years in the construction industry and were structured as the following:

*Table 2: Survey participants' backgrounds*

| Sector | Number of respondents |
|---|---|
| Contractor – Engineering & Design | 14 |
| Contractor - Operations | 6 |
| Consultant – Engineering & Design | 9 |
| Consultant - Site | 1 |
| Developer | 3 |

## 5.4. Survey results and analysis:

As discussed in the previous section of this chapter, the total number of participants were 33 coming from different backgrounds within the construction industry and with different levels of experience. Based on the input gathered from the participant, the outcome of the survey will be quantified and evaluated within this section.

The first question as part of this survey aimed to understand the quantity of rework tasks undertaken by the participants in their daily activities, the results in Figure 22 indicates that 42.4% of the participants estimated less than 30% of their daily activities are rework originated or caused which was the most selected option by the participants. Putting that in perspective, a construction sector employee spends around 45 hours per week in duty where 4.5-13.5 hours of that duration is being spent in doing rework tasks. 36.4% estimated rework activities percentage of less than 10%, 12.1% estimated rework activities percentage of less than 50% while only 9.1% of the participated selected “less than 80%” as their estimation.

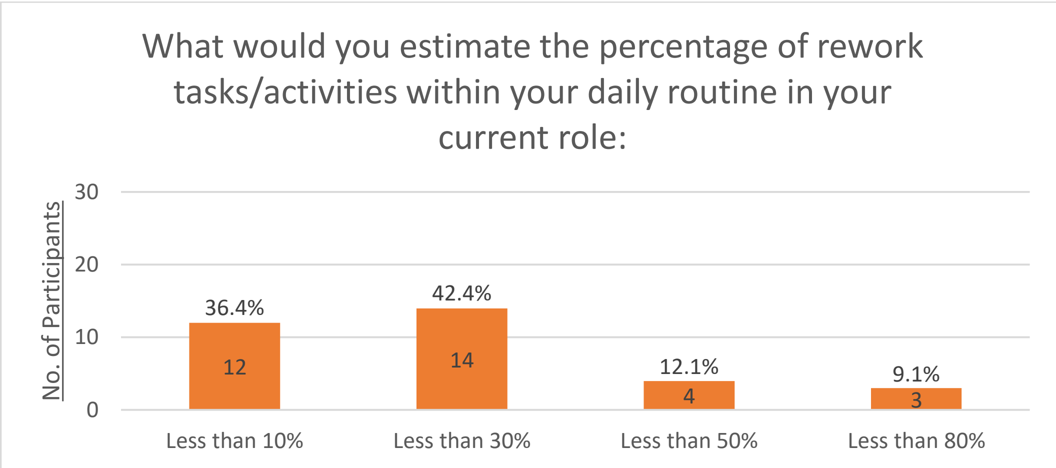


*Figure 22: Respondents opinion on the percentage of rework task each undertakes in their daily tasks*

The sources of rework inducing factors have been evaluated as part of this survey, the results are indicated in Figure 23-27.

Design related factors such as project complexity, the availability and readiness of information, level of coordination and the clarity of the communicated information were rated as the most important factors which induces rework by little over 45% of the participants input. 21.2% of the participants rated the factors as second important whereas the same amount of participant have rated it the least important factor (refer Figure 23).

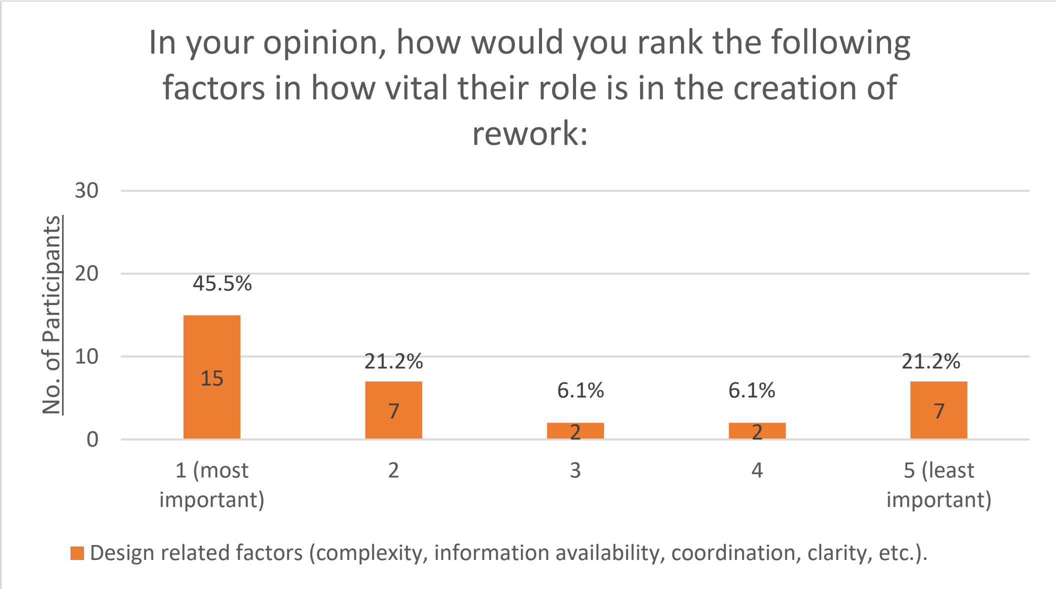


*Figure 23: Respondents opinion in the role of design related factors in the creation of rework*

Contractor related factors such as workmanship levels, planning construction activities and resources and quality control were rated by 30.3% of the participants as the least important factor in inducing rework (refer Figure 24), this value may have to do with the fact that the majority of the participant are from contracting background. Followed by 27.3% of the participants believe that contractor related factors are the second most important rework inducing factors followed by 18.2% rated them as forth, 15.2% rated them as third and only 9.1% rated them as the most important rework inducing factors.

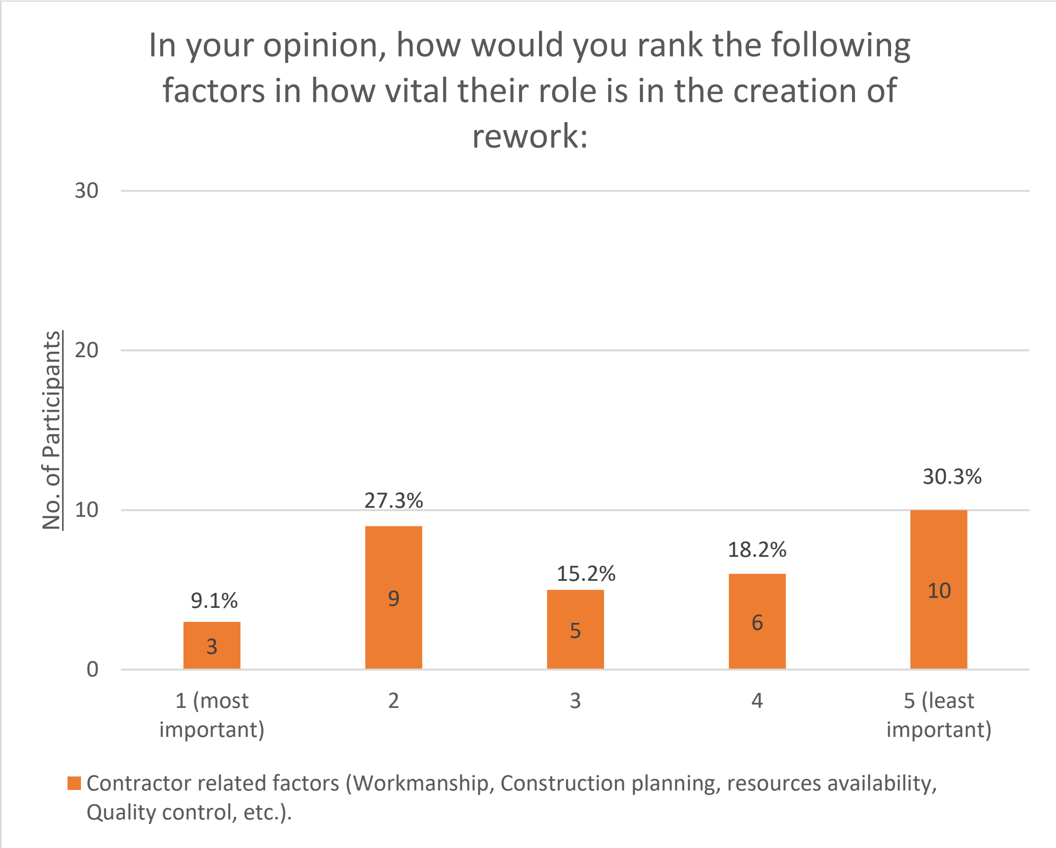


*Figure 24: Respondents opinion in the role of contractor related factors in the creation of rework*

Figure 25 highlights the results of the survey with regards to the role of client related factors such as design changes, design briefing and project budgeting in inducing rework. 30.3% of the participants believed that these are the least important factors in inducing rework during construction. This is followed by 27.3% of the participants who believed that these are the third most important set of factors in inducing rework in construction. While 21.2% believe these factors are the most important where 18.2% believe it is the second most important factors. Only 3% believe them to be the forth in terms of importance from rework induction perspective.

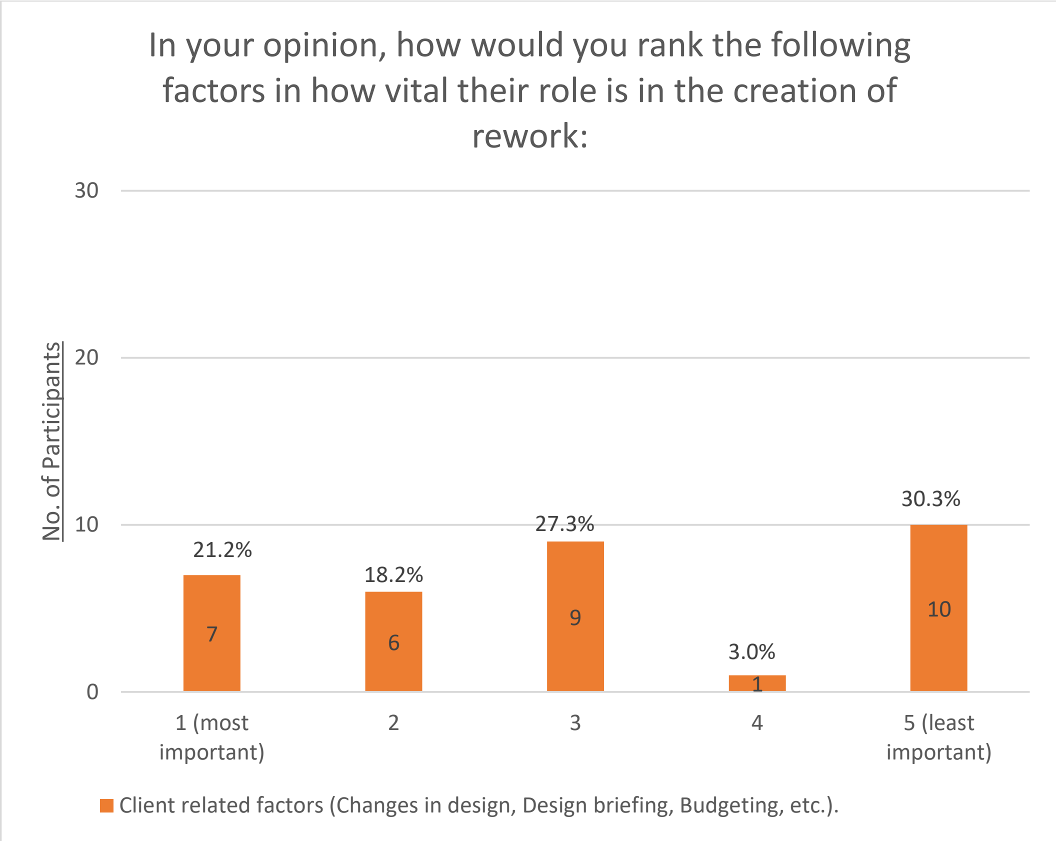


*Figure 25: Respondents opinion in the role of client related factors in the creation of rework*

Project related factors such as site constraints, accessibility & location received the highest rating value within this section of the survey of 48.5%, this value indicated that participant believe that project related factors are the least important factors contributing to rework, percentages of 21.2%, 12.1%, 12.1% and 6.1% of how many of the participants believe these factors should be rated as forth, third, second and first respectively (Figure 26).

The low importance these factors seem to have in reference to the rework causation is potentially due to the fact that site investigations and project location study is given a close evaluation during tendering and project planning. This usually includes the incorporation to the duration and resources required for construction to eliminate site constraints whether before or during the construction process.

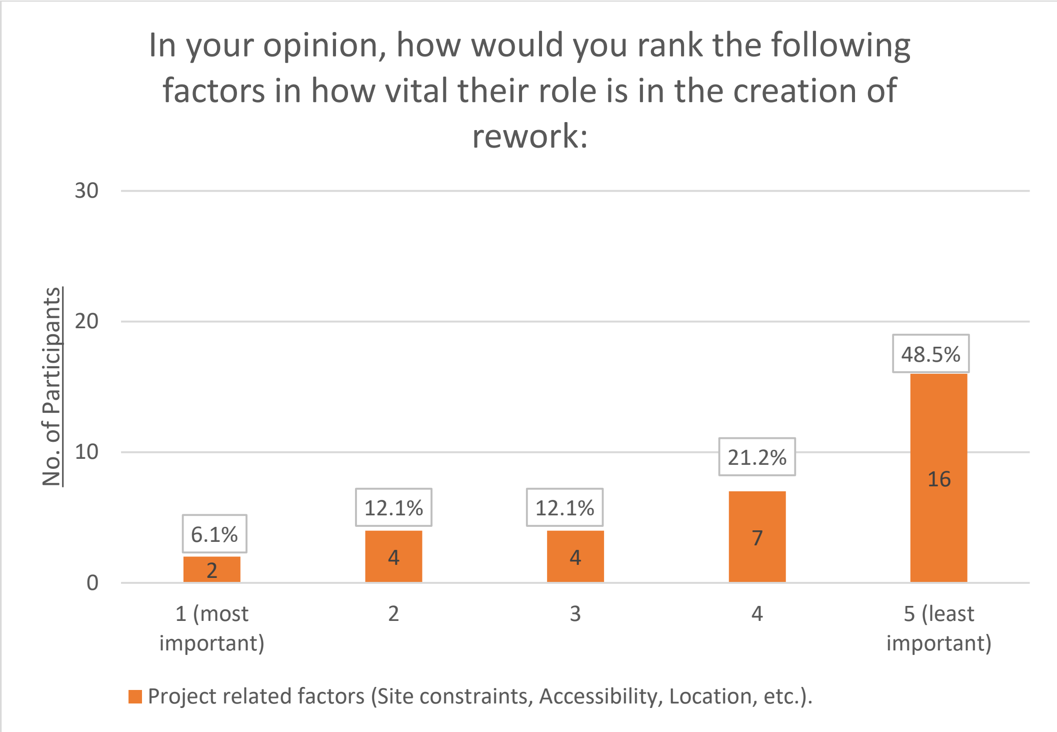


*Figure 26: Respondents opinion in the role of project related factors in the creation of rework*

The impact of external factors such as municipal building codes, economy and security are usually absorbed and dealt with during the design stage of the project by the consultant. This is since construction of a project usually can't commence without obtaining a Building Permit which follows the approval of the relevant authorities of the design as a whole. Furthermore, developers usually study the situation of the economy and the context of the project before commencing with the design and the construction of any development as it has an impact on the anticipated profit behind this development. Therefore, it is probably why 30.3% of the participants believed that these factors play the least significant role in inducing rework, followed by 27.3% of the participants believe that these factors are the fourth most important factors in inducing rework in construction. Then 21.2%, 15.2% and 6.1% of the participants believe that these factors are third, second and most important role respectively in inducing rework in construction.

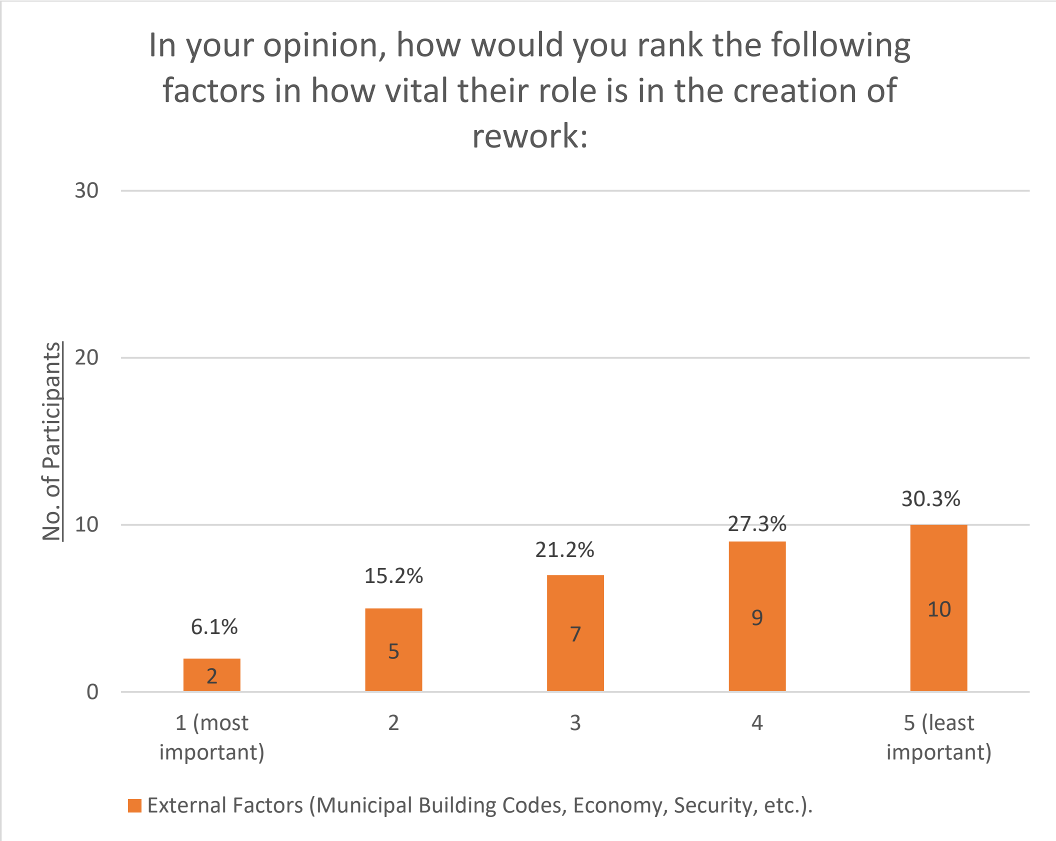


*Figure 27: Respondents opinion in the role of external factors in the creation of rework*

As a conclusion, 45.5% of the participants believe that Design related factors are ranked first in terms of the importance of their role in inducing rework (refer Figure 23). Contractor related factors were rated second with a percentage of 27.3% (refer Figure 24). Client related factors were rated third with a percentage of 27.3% (refer Figure 25). External factors were rated forth with a percentage of 27.3% as well (refer Figure 27) and project related factors were rated as least important with a percentage of 48.5% (refer Figure 26).

The survey also enquired on the particular causes of rework and how significant their impact is on the rework induction in a project. The importance of client / consultant communication during the design briefing stage clarifying the employer’s requirements and what the project needs to achieve in inducing rework was examined within the survey, it was found that 78.8% of the participants believe it to be with very high importance (refer Figure 28). Whereas 15.2% found that this factor is moderately important and only 6.1% of the participants found it to be not important.

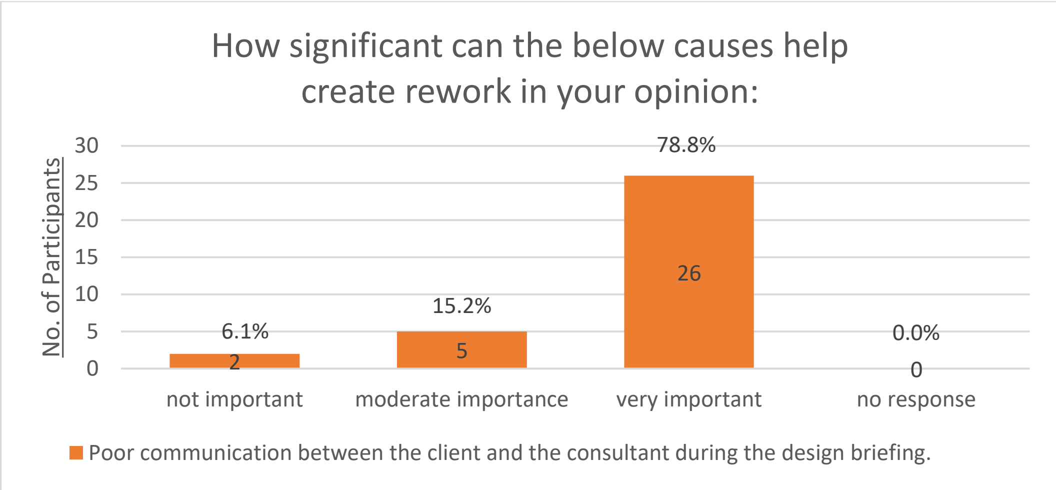


*Figure 28: Respondents opinions with regards to the importance of poor communication between the client and the consultant during the design briefing stage of the project in inducing rework*

Clear briefing by the client to the consultant plays a significant role in reducing rework during design and construction phases of the project as explained in the literature review. This is due to the fact that if the intent is not communicated properly, the provided design and even the executed product may not be satisfactory to the client. Such event would lead the client to issue a design change order or a site instruction to modify the final product.

Communication between the lead consultant and the sub-consultants (or specialized consultants) is considered vital. This is since the lead consultant plays the role of the interpreter of the client's requirements provided in the design brief to the sub-consultants and is the entity who would ensure these requirements are adhered to.

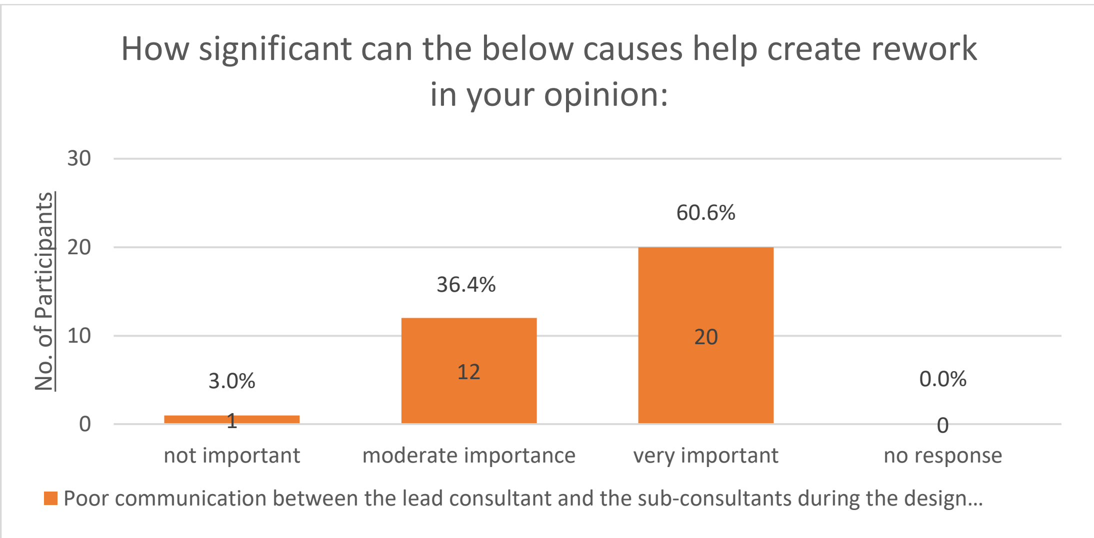


*Figure 29: Respondents opinions with regards to the importance of poor communication between the lead consultant and the sub-consultant during the design stage in inducing rework*

Any deviation from these requirements may lead to rework which seems to be the reason why 60.6% of the participants believes this factor is very important (refer Figure 29). This is followed by 36.4% who found it to be moderately important and only 3% found it to be not important.

The interpretation of the client's requirements within the design brief, the translation of these requirements to both the sub-consultants and the contractors and with the comprehension of the latter two to the same requirements plays a significant role in providing a product that is satisfactory to the client. Achieving alignment with the design intent of the client will reduce significantly virtual and physical rework. This is greatly influenced by the level of expertise both the design and technical teams possess, which is the reason why 54.5% of the participants believe it's lacking plays a very important role in inducing rework in construction projects. 45.5% believe it is moderately important where none of the participants believes it is not important (refer Figure 30).

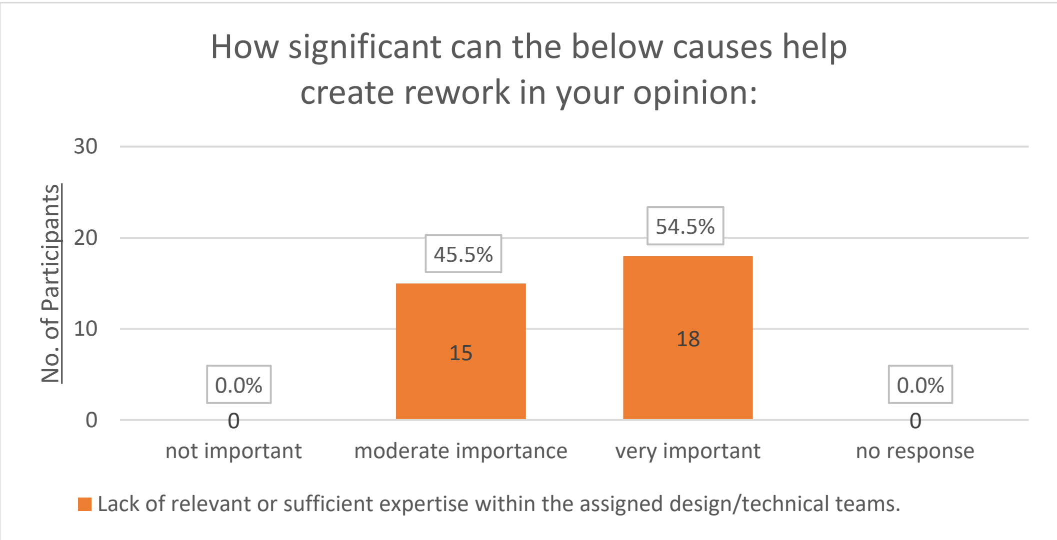


*Figure 30: Respondents opinions with regards to the importance of lack of relevant or sufficient expertise within the assigned design/technical teams in inducing rework*

Contractors are constantly in pursuit for more efficient and more convenient methods to carry out construction activities of various elements of a project. These methods may possibly contribute to design changes as discussed in the literature review chapter (refer section 2.2.1). Such requirements by the contractor may not be foreseen or properly implemented in the design by the consultant. Most of the participants (42.4%) believe this factor have a moderately important role in inducing rework within construction. Whereas 33.3% of the participants believe it to be of high importance and 21.2% believe it is not important (refer Figure 31).

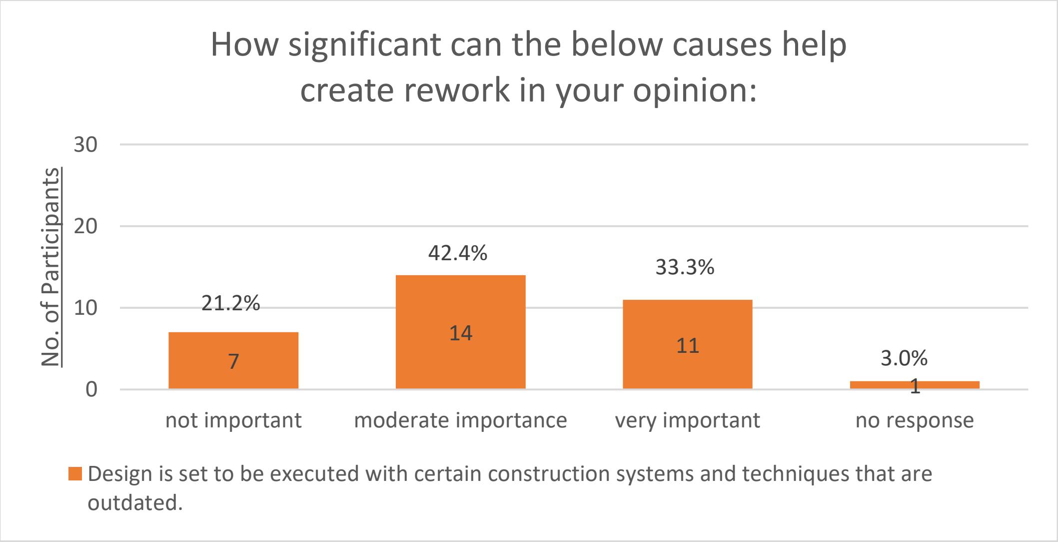


*Figure 31: Respondents opinions with regards to the importance of how updated the construction systems and techniques proposed by the consultant in inducing rework to a project in inducing rework*

As discussed and highlighted in the literature review chapter in this research, information issued as part of the contract documents in a fast track project by the consultant usually lack full comprehension and coordination. Furthermore, poor workmanship and lack of discipline on site may cause errors in execution. Which in return may cause upstream feedback of information back to the technical teams within the contractor as design needs to be revised to accommodate the now existing site condition. These situations often pose additional design load on the technical teams within the contractor which would disturb existing planned processes of design and detailing which are usually connected to execution dates on site.

60.6% of the participants in the survey believe that this disruption aids in inducing rework in construction (refer Figure 32) followed by 36.4% who believe this issue has moderate importance when it comes to inducing rework and only 3% of the participants perceived the same as with no importance.

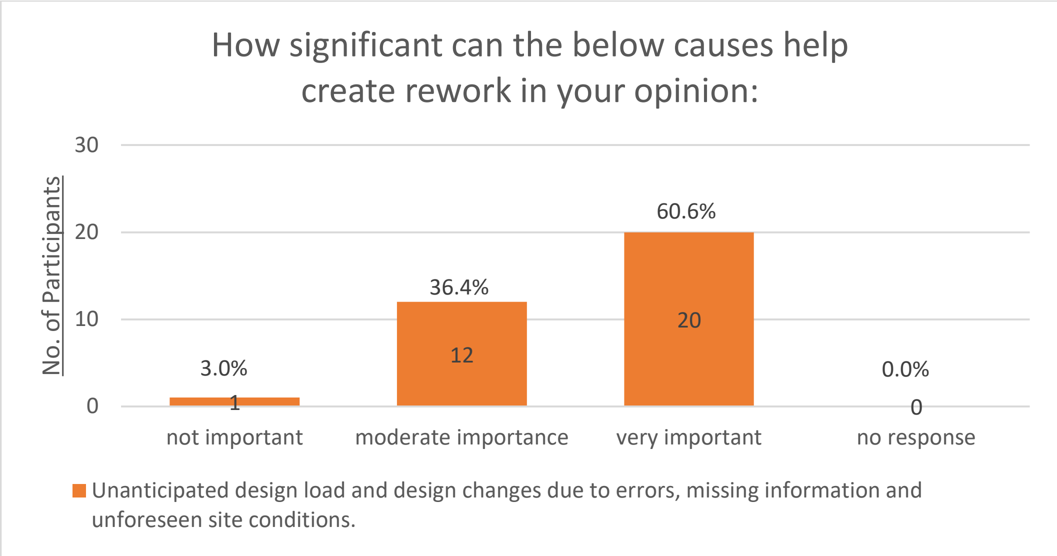


*Figure 32: Respondents opinions with regards to the importance of unanticipated design load and design changes due to errors, missing information and unforeseen site conditions in inducing rework*

One of the many causes of providing comprehension and coordination lacking designs by consultants is due to undertaking competitive bidding process to win a project from a developer, this process usually impact the allowable for design within the proposed fee. Such impacts will be visible on the design process where designers start to exercise what is known as time boxing, it is defined as basically assigning a specific duration for a certain task where any further time spent beyond this duration will incur financial loss to the consultant as a firm.

Such conditions are usually addressed when the contractor gets on board who usually carries out the major portion of design development under the "shy guidance" of the consultant. Most of the participants (60.6%) believe this to be of moderate importance in its role as rework inducing activity; this is followed by 24.2% who believe this issue has a significant importance and only 15.2% believe such practices has no impact of rework induction (refer Figure 33).

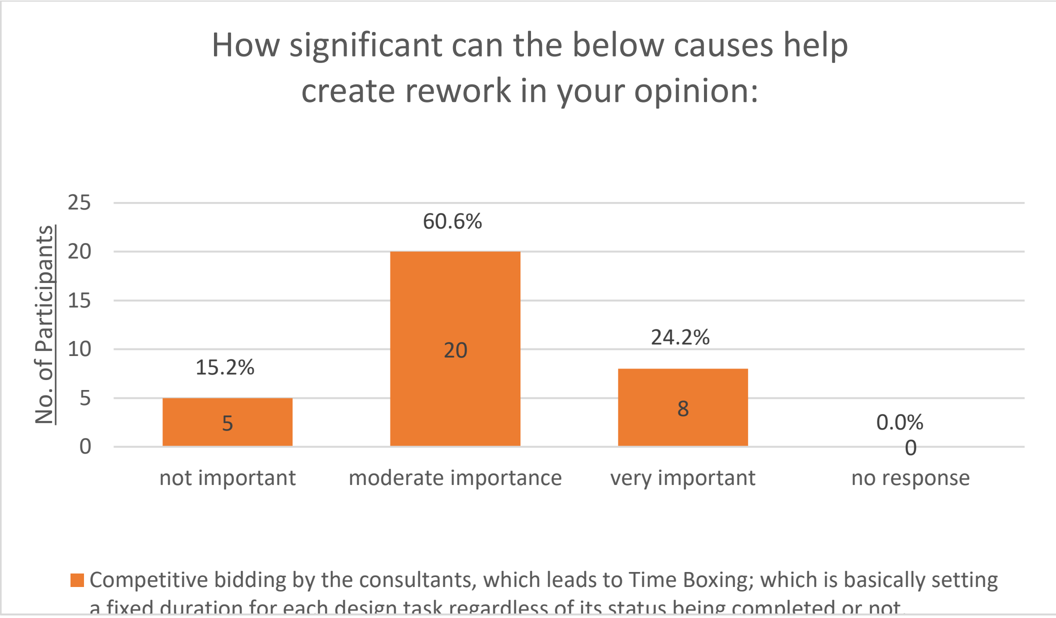


*Figure 33: Respondents opinions with regards to the importance of competitive bidding by the consultants in inducing rework*

Construction planning plays a significant role in providing calculated estimates of when would a project is handed over to the client for operation. These estimates are based on fixed duration for each particular construction activity, such activities are sequenced in a manner that is logical to provide proper accessibility, reduce rework, etc. For an activity to start, proper information should be present. One of the reasons of missing information is work pressure on technical teams. This scenario is usually temporarily remedied by providing some sort of "advanced information" which is basically immature information for site to commence the work until full coordination and development is concluded.

Such practices can backfire should the information come back rejected from the consultant or when further development to the design forces the technical team to change the information that was issued originally. This seems to be the cause for the fact that only 6.1% of the respondents believe that this issue doesn't contribute to rework induction in construction (refer Figure 34) where almost 94% of the total respondents believe that such issue has moderate to significant importance in inducing rework to construction (42.4% and 51.5% respectively).

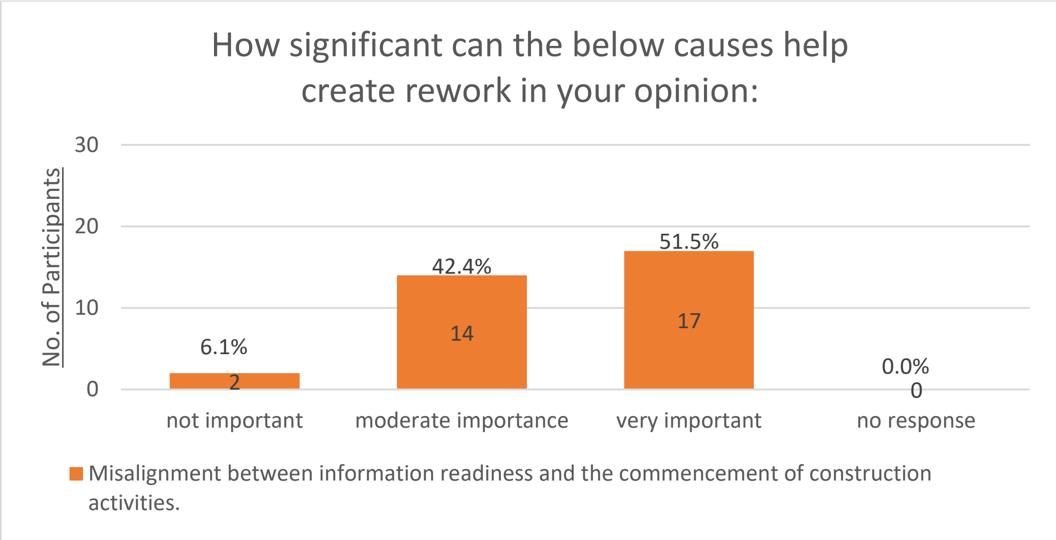


*Figure 34: Respondents opinions with regards to the importance of the misalignment between information readiness and the commencement of construction activities in inducing rework*

Construction projects are becoming more and more complex not only in their design but also in their delivery methodology. Even if a certain project is simple in its design, it can encourage the client to enforce a fast delivery program on the contractor which would put the contractor in a position where the involvement of specialists become necessary. Upon the involvement of such specialists, who can range from façade contractors to concrete jump form or tower crane suppliers; they become stakeholders within the project where their requirements need to be fulfilled in order for their role to be carried out. Otherwise, their presence my become a burden rather than an aid. An example would be the interface between the concrete casting team and the jump form team where if no sufficient provisions where provided by the concrete team for the jump form to climb, this innovative system may become a nightmare should its requirements not be catered for.

However, due to the common usage of these methodologies, contractors became aware of the requirements of most of such methodologies and would provide provisions for the same even if such parties are not involved in the project early on. This seems to be the reason why 51.5% believe this issue to be of moderate importance in inducing rework in construction. 33.3% believes the issue to be of high importance whereas only 12.1% of the participants believe this issue is not important in creating rework during construction (Refer Figure 35).

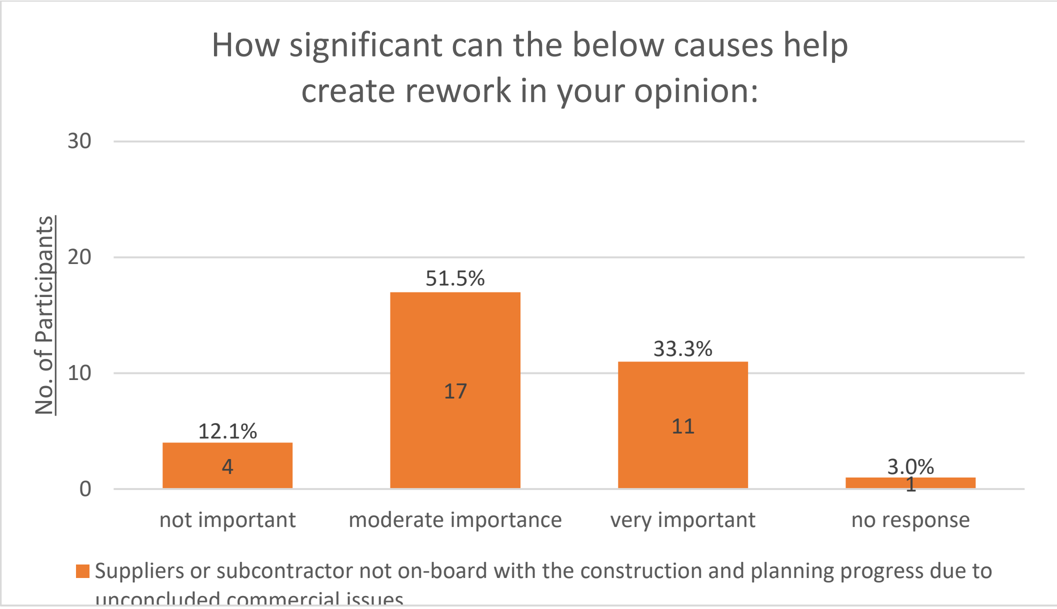


*Figure 35: Respondents opinions with regards to the importance of failing to engage suppliers and subcontractors early on in the project to involve them in the construction process due to financial issues in inducing rework*

Information technology have been playing a significant role in the construction industry in terms of improving the tools used to create, transfer, process and maintain information between different parties. However, these tools are operated by technical and operations teams which without their input and active participation, the benefit of such tools will be rendered null.

Therefore, despite the advances in information technology, projects till date still face problems with information in terms of accuracy and comprehension as such values rely more on the technical teams' qualities such as awareness, amount of work in hand and their ethics rather than the technology the teams are using. Meaning that the will to carry on a task (including being aware that this task should be done) comes higher in importance rather than the tool in which the task is to be carried out with. This goes in line with the result of the survey where 54.5% of the participants believe that this issue has moderate importance in inducing rework followed by 27.3% and 18.2% of the participants who believe this issue is very important and not important respectively (refer Figure 36).

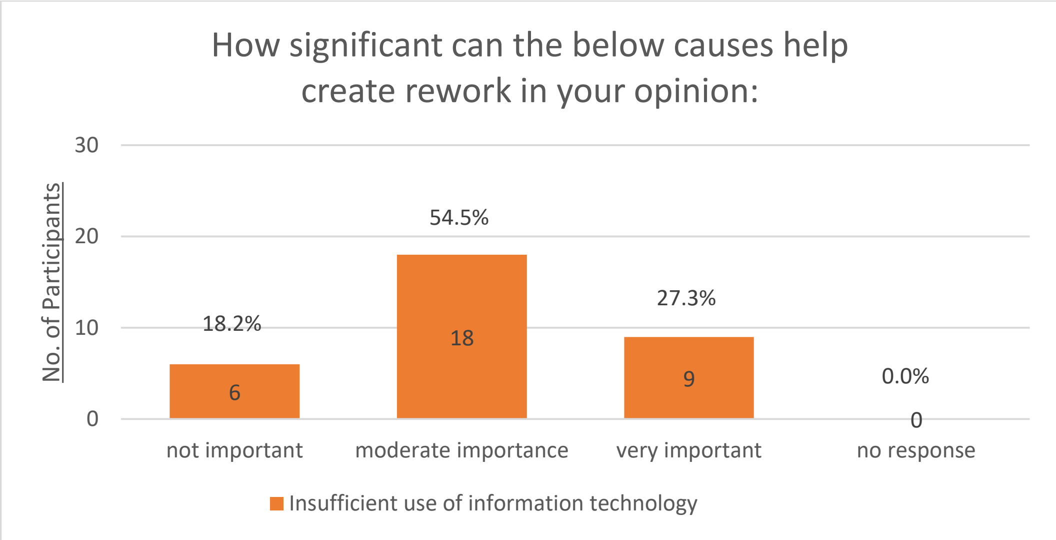


*Figure 36: Respondents opinions with regards to the importance of insufficient use of information technology in inducing rework*

Poor execution skills in construction can cause the executed work to be revisited spending more resources in rectification, such issues play a further significant role in creating pressure on following planned activities as more will have to be done with the same resources than what was planned. 51.5% of the respondents to the survey believed this issue to be of high importance in rework induction. 33.3% believes this issue have a moderate importance where 12.1% believe this issue have no importance in inducing rework (refer Figure 37).

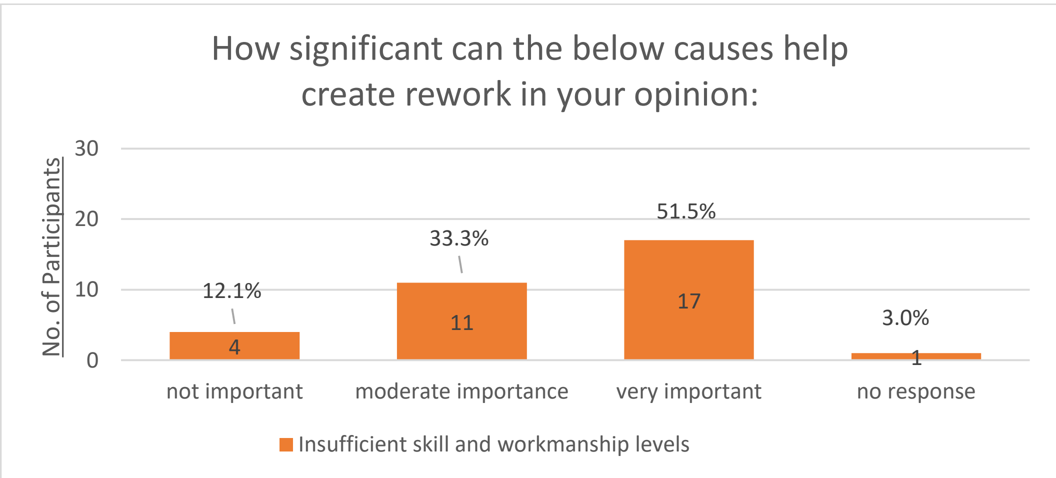


*Figure 37: Respondents opinions with regards to the importance of insufficient skill and workmanship levels in inducing rework*

Design changes issued form the client is usually a result of nonconformance of the design intent with the design brief, inaccurate representation in the contract documents or missing information. This can extend to changed or updated requirements by the client especially when some changes are requested from the future tenants.

Such changes can disturb the flow of design and detailing carried out by the design team within a consultant or the technical team within the contractor. The impact of change becomes bigger the more delayed the change occurs.

Furthermore, there would be a physical rework should the change in requirements address certain elements in the project that are already executed, this would include additional resources for removing the existing the element and even more resources to do it again as per the revised client's requirements.

These issues are some of the reasons why 60.6% of the respondents believe that this issue plays a significant role in inducing rework in construction (refer Figure 38) followed by 30.3% who believe the issue to be of moderate importance whereas only 9.1% of the participants believe this issue has no importance what so ever.

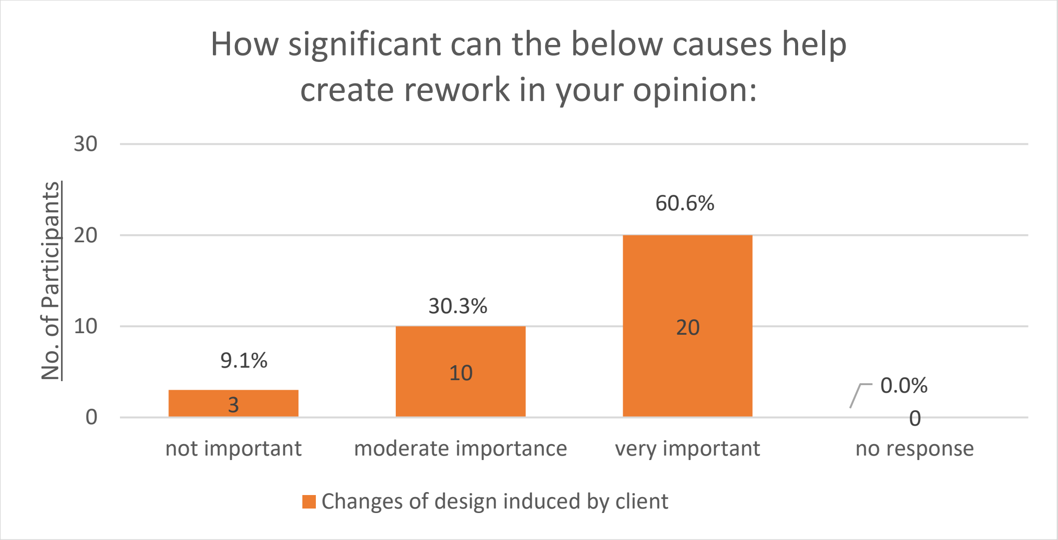


*Figure 38: Respondents opinions with regards to the importance of changes of design induced by Client in inducing rework*

No matter how good the construction planning of a certain project is, disruptions of cash flow to that project can bring a project to a complete halt due to the unavailability of resources. This condition may require additional work of removing temporary construction related elements (such as scaffoldings) and providing protection for existing and installed elements so that they won't be damaged during the duration of project's stop.

Furthermore, construction teams will usually have to restart what was previously stopped with a few steps back so as to re-understand the task in hand when a project restarts, which can cause a significant setback in the project. 78.4% of respondents believe this issue to be of moderate (36.4%) to high (42.4%) importance in inducing rework in construction (refer Figure 39). Whereas 15.2% believe this has not an important role in the creation of rework.

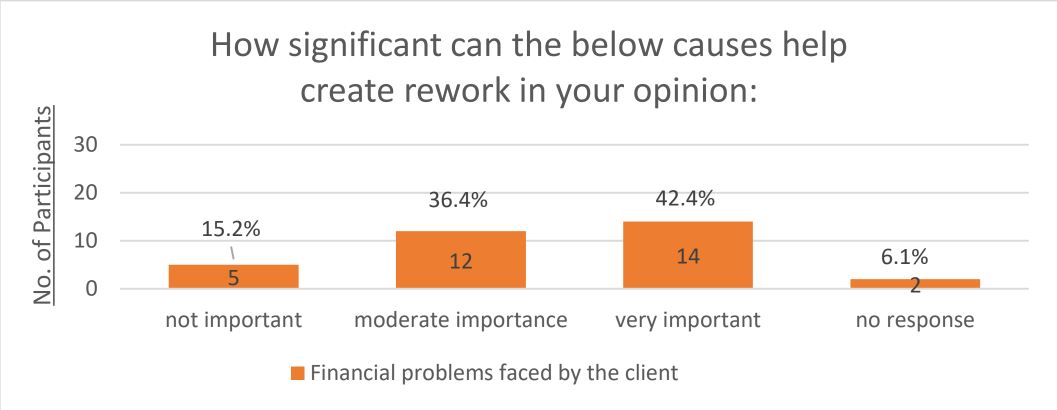


*Figure 39: Respondents opinions with regards to the importance of the impact of financial problems faced by the client in inducing rework*

Design and project halts can also be caused by client's failure to take a decision in selecting his preference for various reasons. As discussed earlier, such halts can have a significant impact on the status of the project and may lead to abortive works in the process. Despite of the previous note, most of the respondents (54.5%) believe that this issue has a moderate importance in inducing rework in construction. Whereas 36.4% of the participants believe it has a significant level of importance and little over 6% believe this issue plays an insignificant role in inducing rework (refer Figure 40).

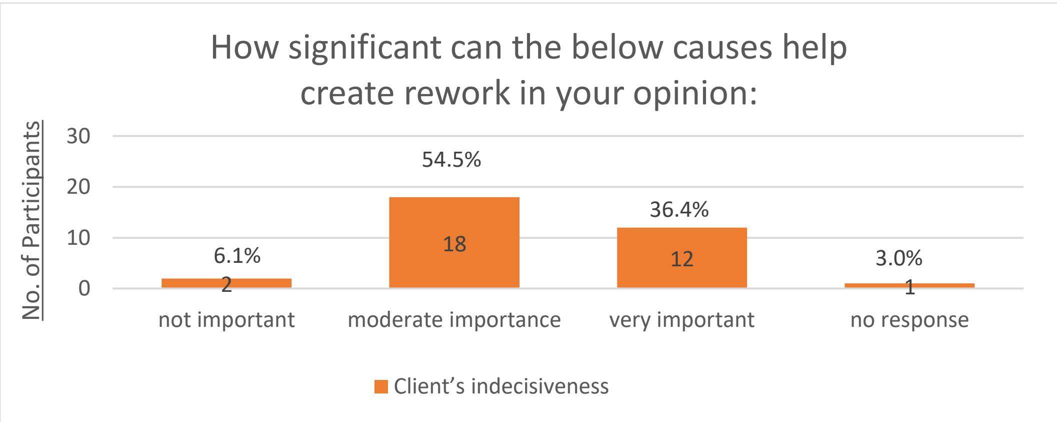


*Figure 40: Respondents opinions with regards to the importance of client's indecisiveness in inducing rework*

An almost similar vote by the respondents with 60.6% which believed that client's insistent nature have a moderate importance in inducing rework in construction, such as when the client would push the consultant to issue the contract documents despite their level of readiness. 21.2% of the respondents believed that this issue plays significant role in inducing rework while 15.2% believe it doesn't have a valuable role in creating rework (refer Figure 41).

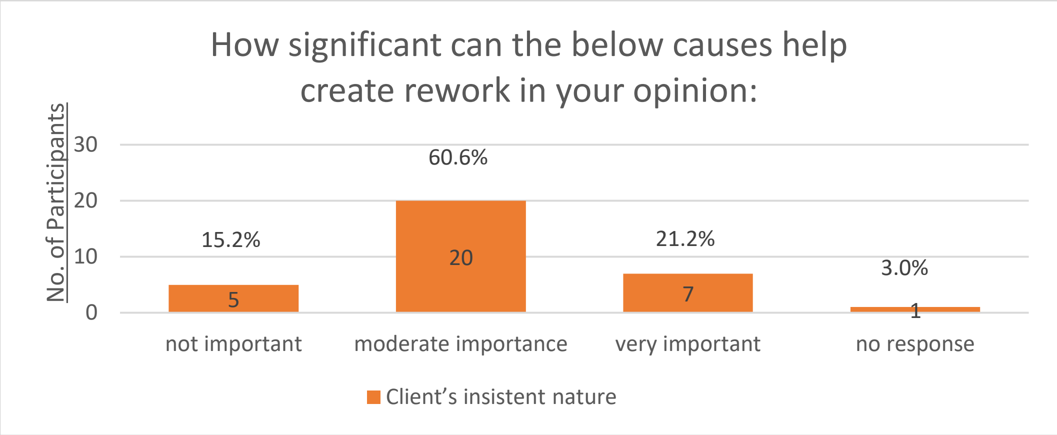


*Figure 41: Respondents opinions with regards to the importance of client's insistent nature in inducing rework*

Site conditions plays a significant role in shaping the design of a project therefore failure to understand and analyze it can result in a non-workable design which may create both virtual and physical rework. Therefore, 87.9% of the participants believe this issue plays a moderate (39.4%) to important (48.5%) role in the creation of rework during design and construction of a project while only 6.1% believe this issue to be insignificant in creating the same (refer Figure 42).

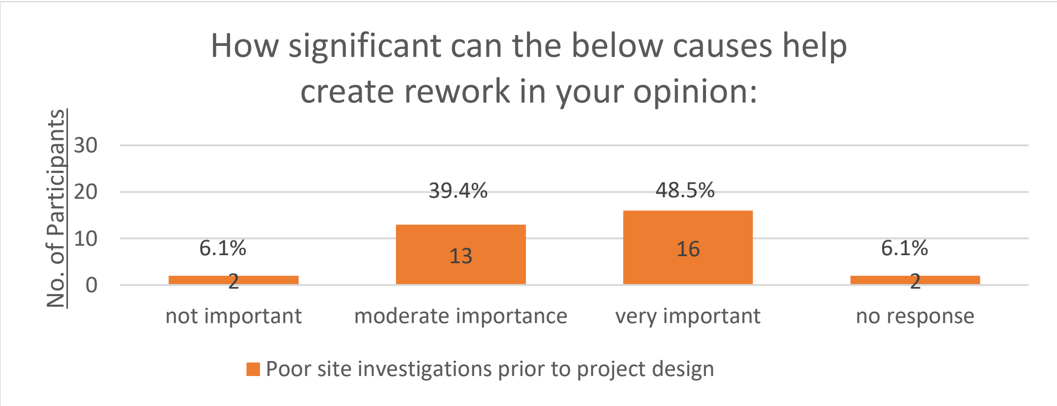


*Figure 42: Respondents opinions with regards to the importance of poor site investigations prior to project design*

Over 93% of the respondents stated that the issue of poor managerial qualities in construction plays a moderate (33.3%) to very important (60.6%) role in inducing rework in construction, the reason for that would probably be the fact that construction management play a significant role in ensuring planned activities are executed when due. Furthermore, the management should ensure that preventive and remedial actions are carried out where relevant. Only 3% believe this issue has no importance in inducing rework (refer Figure 43).

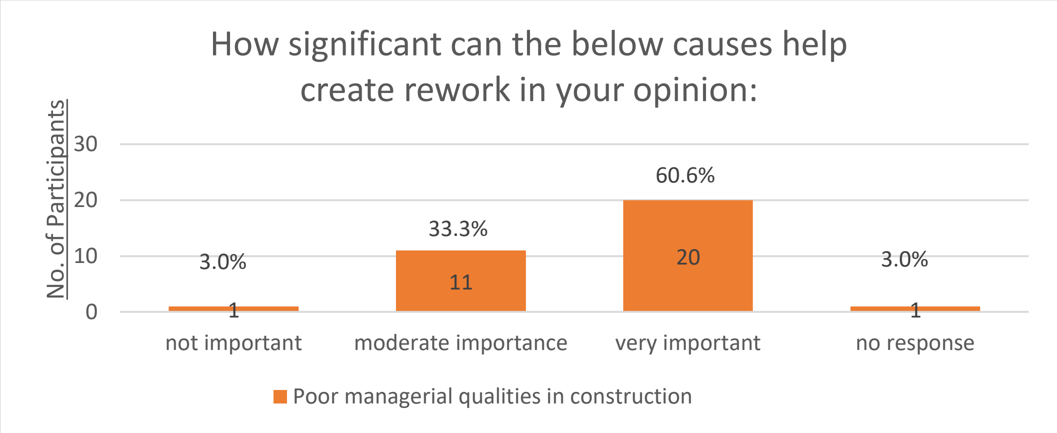


*Figure 43: Respondents opinions with regards to the importance of poor managerial qualities in construction in inducing rework*

Design changes due to instructions and/or design development is becoming a dynamic feature in construction projects for various reasons as discussed before. Such changes when introduced to the design may not be circulated properly to all the operations teams as it can be an email between a limited group of individuals which may not reach to all relevant parties.

51.5% of the participants in the survey believe this matter to be of high importance in inducing rework followed by 36.4% who consider it to be of moderate importance in its role of inducing rework while only 6.1% see this issue as not important (refer Figure 44).

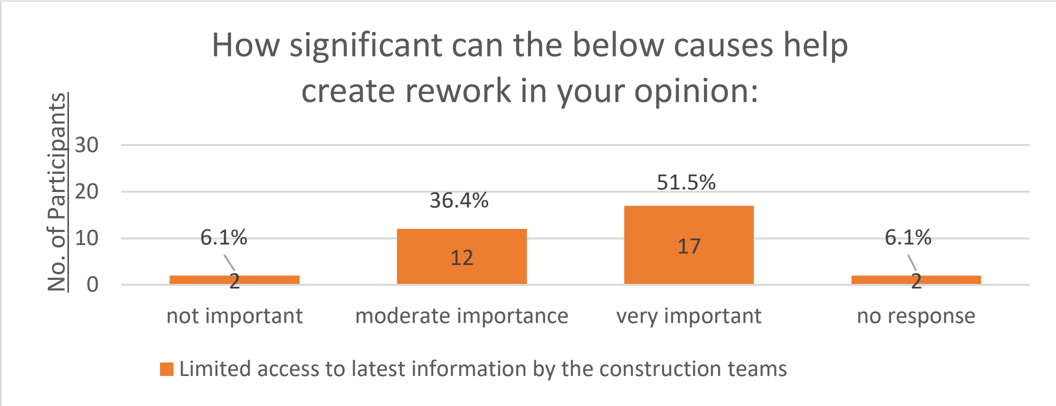


Figure 44: Respondents opinions with regards to the importance of limited access to latest information by the construction teams in inducing rework

Figure 45 indicates that 96.9% of respondents believe that the lack of discipline between different parties in construction plays a very important (63.6%) to a moderately important (33.3%) role in inducing rework in construction. This is because such issue can encourage out of sequence work progress.

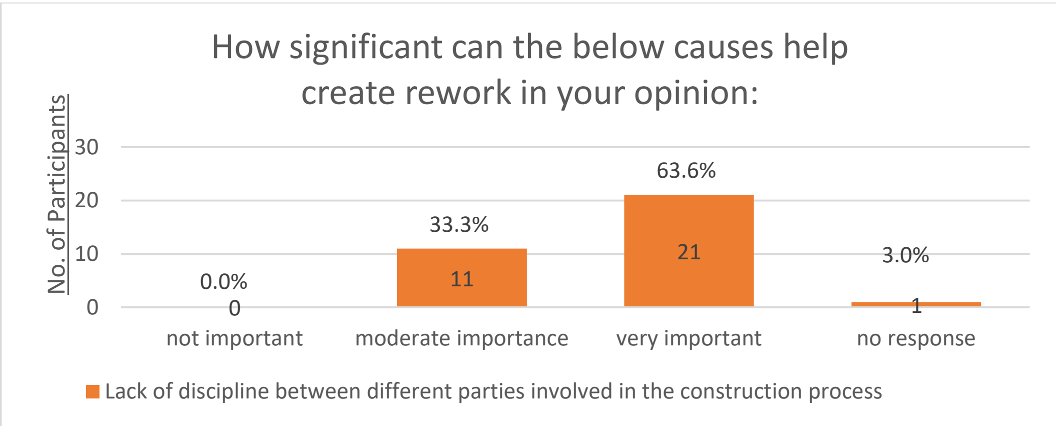


*Figure 45: Respondents opinions with regards to the importance of lack of discipline between different parties involved in the construction process in inducing rework*

Lack of construction resources was found to be of high importance in its role in inducing rework as per 45.5% of the participants of the survey. This is followed by 30.3% of the participants who believe this issue has moderate importance. Whereas only 18.2% cited that lack of resources have little to add in inducing rework in construction (refer Figure 46)

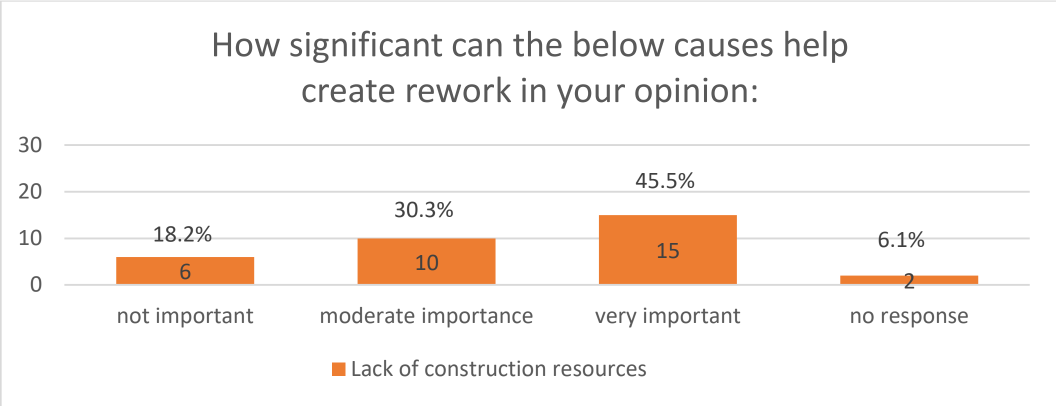


*Figure 46: Respondents opinions with regards to the importance of lack of construction resources in inducing rework*

Planning plays a significant role in determining whether a construction project would be successful or not. This is because it ought to predict the requirements of different stages and activities in the construction process while governing the sequence of which these activities are carried out. Furthermore, it provides a reference guide to scale progress on site. This is potentially why 63.6% of the participants believe its lacking plays a significant role in creating construction rework. 24.2% of the participants believe it to have a moderate importance in creating rework whereas only 9.1% think that the lack of planning plays an unimportant role in inducing rework (refer Figure 47).

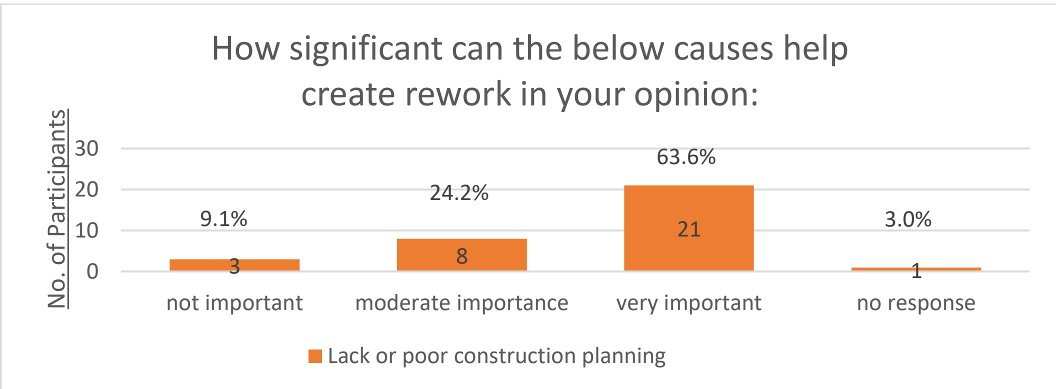


*Figure 47: Respondents opinions with regards to the importance of lack or poor construction planning in inducing rework*

Experience is an important tool in avoiding making mistakes during both design and construction as it brings the knowledge of the conditions of previous events along with why were these events considered a success or a failure. Furthermore, it brings onboard the know-how on what works best and how to do it.

75.8 % of the respondents of the survey believe that not learning from previous mistakes plays a very important role in rework creation and 18.2% believe it plays a role with moderate importance. However, only 3% believe such matter has no importance in the creation of rework (refer Figure 48).

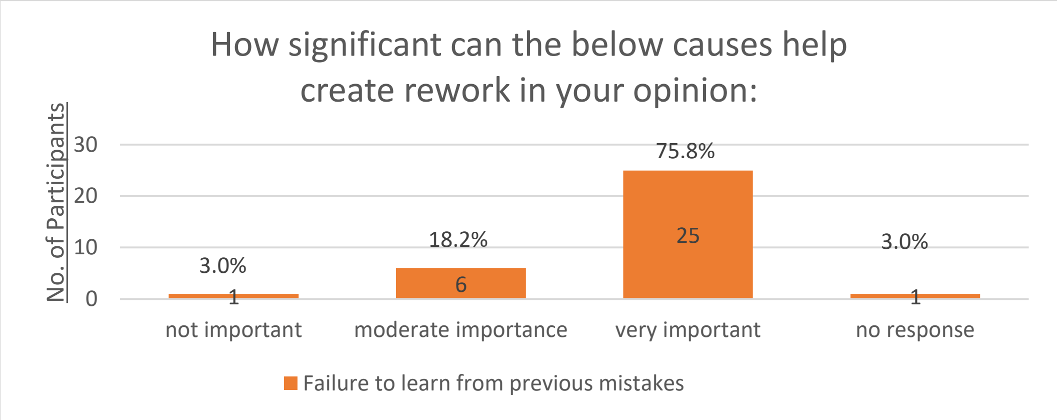


*Figure 48: Respondents opinions with regards to the importance of failure to learn from previous mistake in inducing rework*

The third part of the survey consisted of proposals suggested by the author as measures to prevent or reduce rework in construction for the survey participants to rate in terms importance. 66.7% of the respondents believe that the early appointment of the technical teams within the contractor plays a significant role in reducing rework (refer Figure 49). This is because the technical team will have sufficient time to understand the project requirements and pin point problematic issues within the design. Furthermore, they will be able to highlight the same to the consultant and the client through RFIs or within technical meetings. 24.2% of the participants believe this have moderate importance in reducing rework and only 3% believe this will not have an impact on reducing rework in construction.

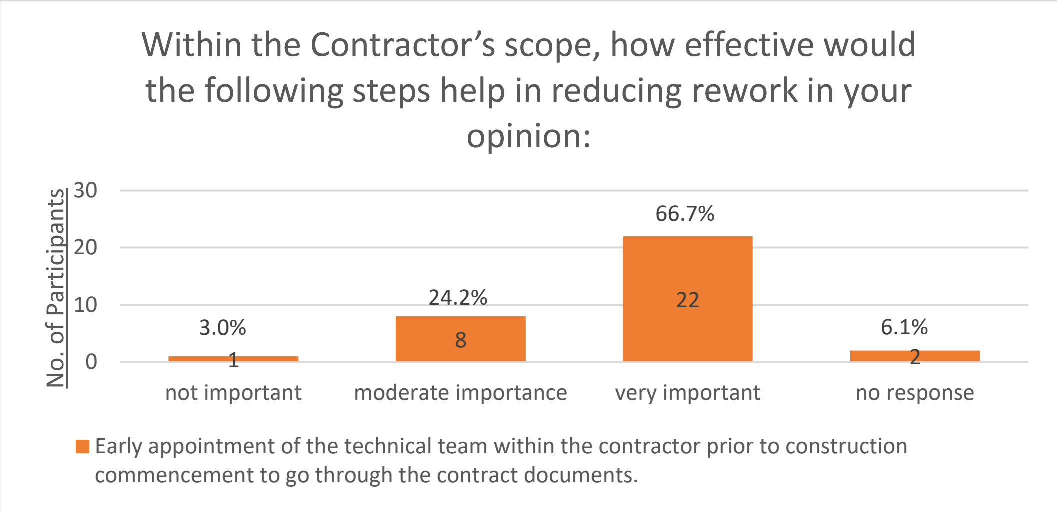


*Figure 49: Respondents opinions with regards to the importance of early appointment of the technical teams within the contractor prior to construction commencement to go through the contract documents in reducing rework*

The second proposal introduced in the survey was imposing cost and time impacts on the client should there be a miss-coordination or missing information in the contract documents. This can be justified as even if remedial actions are taken by the consultant at that stage, work will have to halt on site in anticipation of new information from the consultant. Such information may have financial impacts on the contractor caused by material waiting time, site operation, etc. Moreover, the contractor undertakes design development activities to expedite the process creating disruption to the overall design development and detailing planning.

However, it is to be noted that the standard practice followed in the region forces the contractor to take liability on the constructed project and to ensure it is aligned with relevant codes and regulations. Therefore, the contractor usually undertakes such design development (to a certain extent) in order to get moving with construction. Which is probably why more respondents believe this has a moderately important role (48.5%) in reducing rework where as 45.5% of the respondents think this plays a very important role achieving the same (refer Figure 50).

Almost the same goes to the idea of imposing cost and time impacts in the event of changes in the design during the construction on the client. Which usually is a major source of disruption to both design development and execution. Yet clients usually hide behind the fact that a certain element hasn't been built yet so changing its design mustn't have an impact on the progress of the project. The same is usually agreed upon by the management in the contractor side to illustrate flexibility and intention to serve the client. Furthermore, some clients anticipate any delay in the contractor's progress in the delivery of the project as it will allow them to hide behind concepts such as "concurrent delay". This condition allows the client to issue design changes which the contractor cannot claim extra time for since the contractor is already in delay. Therefore, forcing the contractor to accept such changes should they be cost neutral and only involve re-engineering.

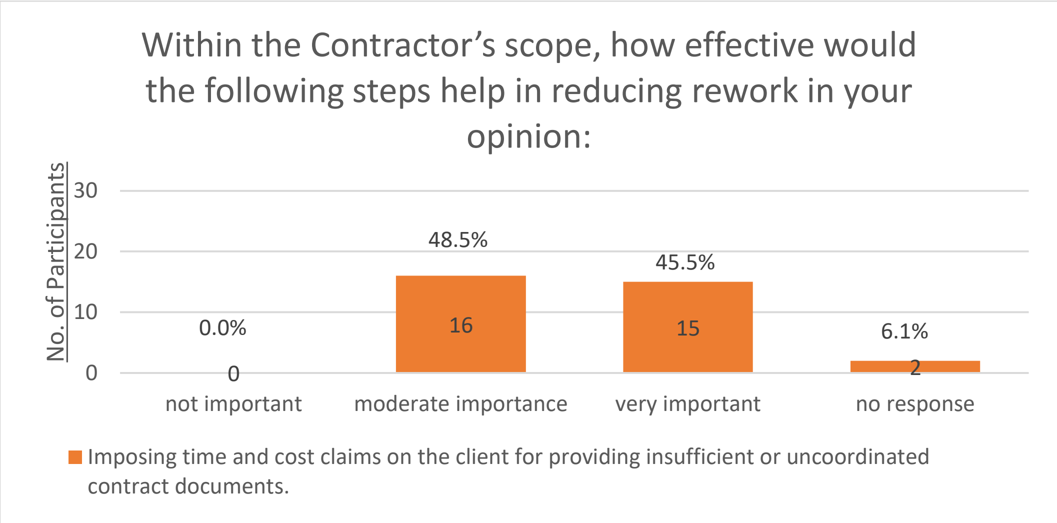


*Figure 50: Respondents opinions with regards to the importance of imposing time and cost claims on the client for providing insufficient or uncoordinated contract documents in reducing rework*

The modification of the design then gets pushed down to the technical team of the contractor for processing. The technical teams usually struggle to keep the information flow to the operation team while accommodating design changes and re-coordination from the client. This is probably the reason why 57.6% of respondents believe this can significantly reduce rework on site while 36.4% think it has a moderate effect to do the same (refer Figure 51).

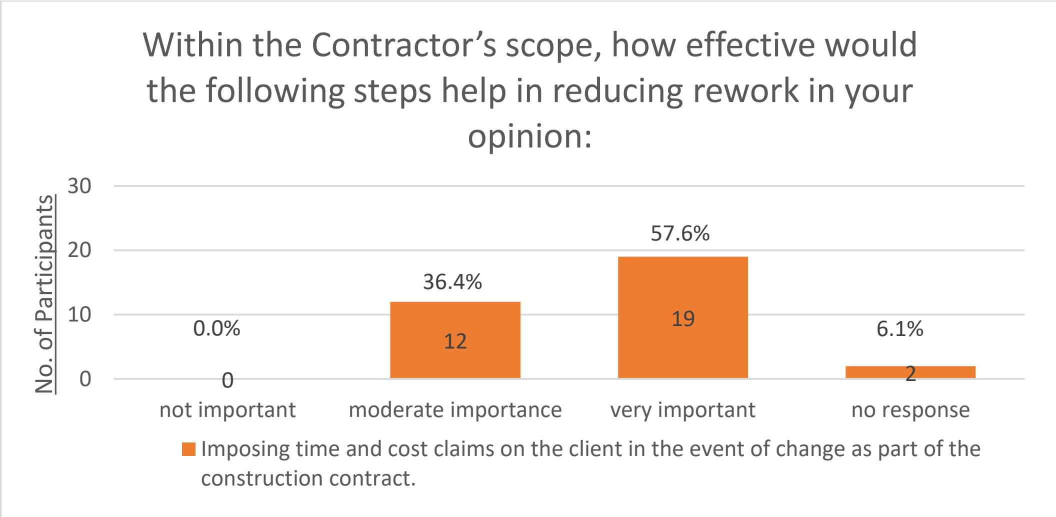


*Figure 51: Respondents opinions with regards to the importance of imposing time and cost claims on the client in the event of change as part of the construction contract in reducing rework*

Involving all the stakeholders of a project in the coordination process early on in the project plays a significant role in reducing rework (especially virtual). This is due to the fact that all the requirements from different parties are communicated to other relevant parties early on. Which would allow each entity to have minimum work do-overs.

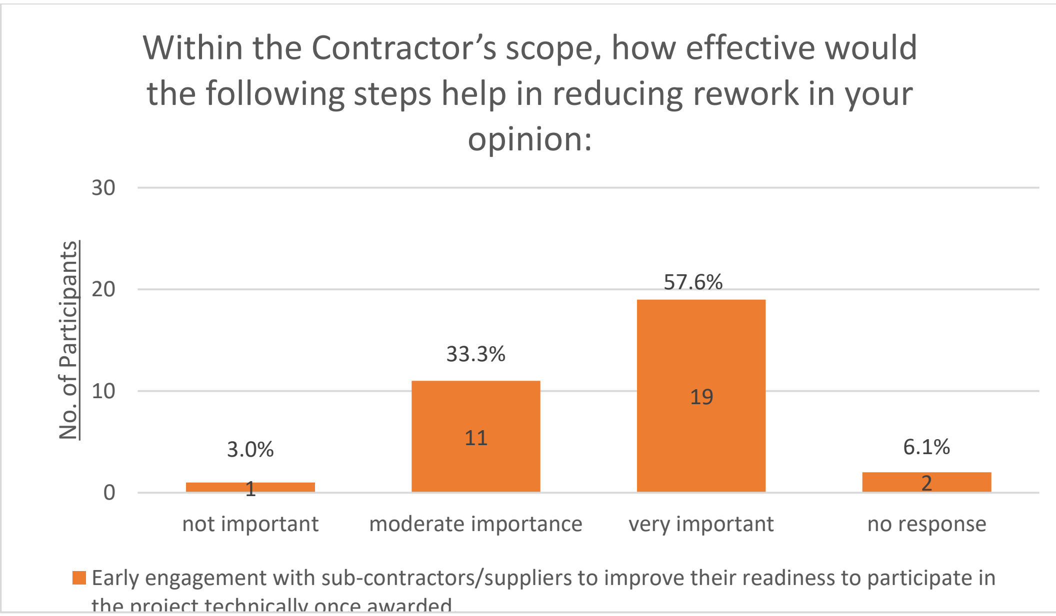


*Figure 52: Respondents opinions with regards to the importance of early engagement with subcontractors / suppliers to improve their readiness to participate in the project once awarded in reducing rework*

57.6% of respondents believe that this factor plays an important role in reducing rework, 33.3% of the respondents think it has a moderate impact and only 3%

believe early coordination has an unimportant impact on rework reduction (refer Figure 52).

The seamless operation of coordination processes in construction depends significantly on managing different stakeholders' expectations as in who will do what and when. This can take place by pre-identifying this flow in a responsibility matrix, allowing different entities to know when to start doing their share of the work while having what is needed from other preceding entities. This can play a significant role in reducing rework in construction. This conclusion seems to be the reason why 60.6% of the respondents believe this step have an important impact in reducing rework. 27.3% believe this has a moderate impact and only 6.1% believe this has a low impact on reduction in rework (refer Figure 53).

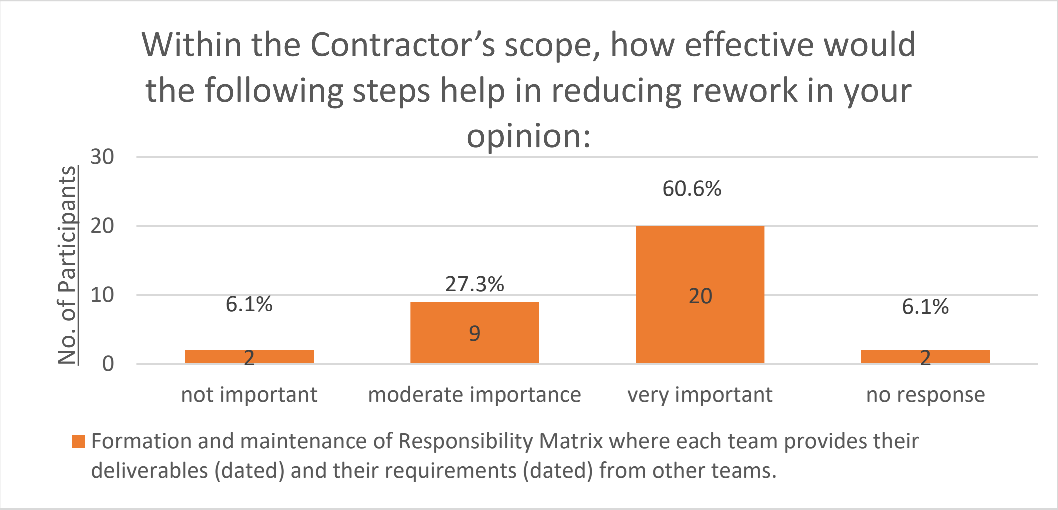


*Figure 53: Respondents opinions with regards to the importance of the formation and maintenance of Responsibility Matrix where each team provides their deliverables (dated) and their requirements (dated) from other teams*

Failure to implement a proper responsibility matrix where different stakeholders know when to expect what can lead to work commencing without having all required information in hand. This would force work to be redone once the balance information became available or else delay the work execution.

Assuming other stakeholders also progressed on the previously issued information, the information they produced will be based on an out dated base information. Moreover, usually work will proceed on site until the operations teams realize that what has been executed is different from the revised base information. Therefore, the current design doesn't fit the site condition and needs to be revised creating virtual rework. Which is why 60.6% of the respondents believe that implementing a system of dependency where the modification of base information would render the dependent information outdated plays an important role in reducing rework. 27.3 % consider this to have a moderate effect whereas 6.1% consider this to have low importance in reducing rework (refer Figure 54).

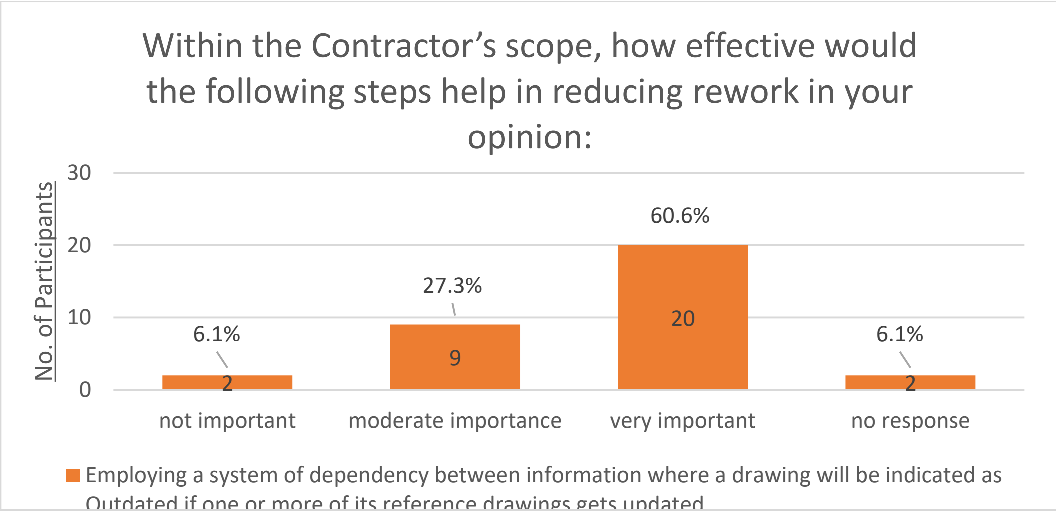


*Figure 54: Respondents opinions with regards to the importance of employing a system of dependency between information where a drawing will be indicated as "outdated" if one or more of its reference drawings gets updated*

Out of sequence work has always infected construction sites with rework as everyone will work everywhere when they have the resources and access which would create chaos on site. Therefore, 54.5% of the participants think that implementing a monitoring and reporting system to track work on site and report progress is a very important contributor to reducing rework in construction followed by 36.4% who believe this plays a moderate role (refer Figure 55).

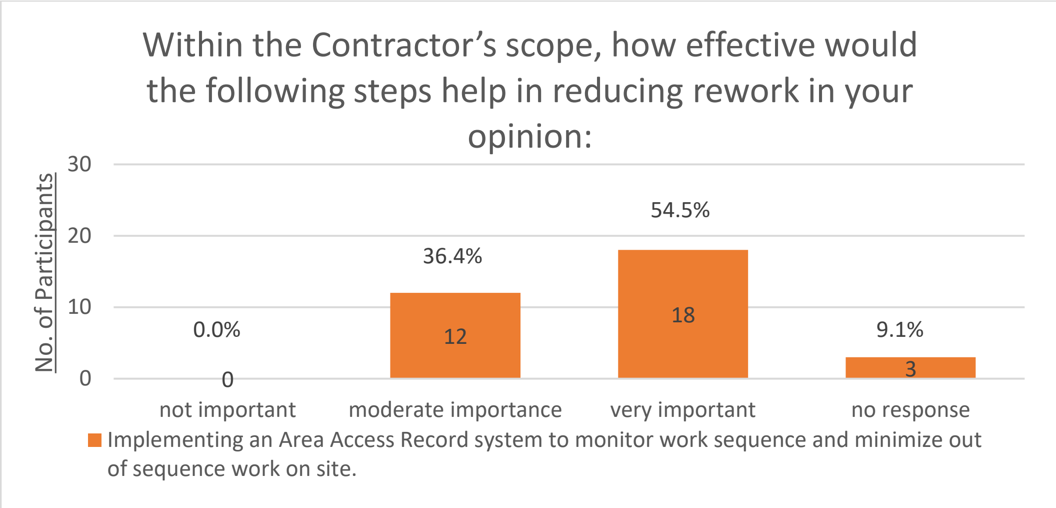


*Figure 55: Respondents opinions with regards to the importance of implementing an Area Access Record systems to monitor work sequence and minimize out of sequence work on site*

Constructability reviews where the technical teams of the contractor discuss with the operations teams possible methodologies of erecting an element on site is suggested in the survey as a mean to reduce rework on site. The technical teams would allow the feedback from such meetings to influence the design to simplify the construction process. Furthermore, constructability reviews extend to planning the construction process to understand the context and the limitations of working in a certain area. Allowing different teams to plan their tasks which would help reduce rework due to proper planning. Therefore, 54.5% of respondents believe this is very important in reducing rework followed by 39.4% believe this to be a moderate importance (refer Figure 56).

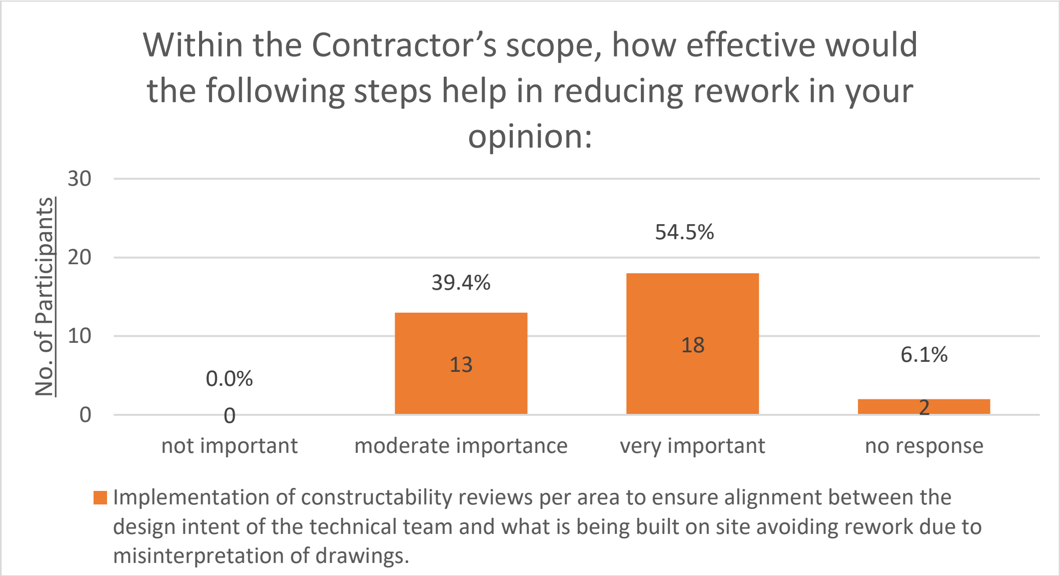


*Figure 56: Respondents opinions with regards to the importance of implementation of constructability reviews per area to ensure alignment between the design intent of the technical team and what is being built on site avoiding rework due to misinterpretation*

Establishing a single communication platform with open access to all information helps keep all parties up-to-date and reduces the chance of proceeding with outdated information on site. Which is why over 75% of the participants believe this plays a significant role in reducing rework in construction site. This is followed by 12.1% who think this factor has only moderate importance and 6.1% believe this has little importance in reducing rework (Refer Figure 57).

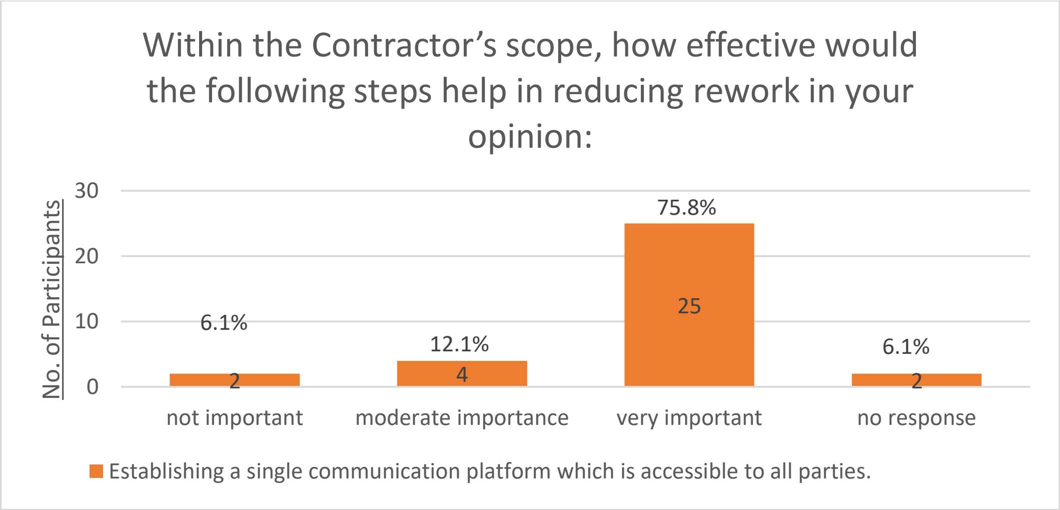


*Figure 57: Respondents opinions with regards to the importance of establishing a single communication platform which is accessible to all parties*

The forth part of the survey focuses on BIM and its level of implementation in different firms along with the driver behind that level of implementation. Over 22% of the participants in the survey have no perceivable BIM implementation scheme in their firms. Whereas over 58% of the participants indicated that they have a semi implementation scheme where only limited portions of BIM have been utilized. The rest of the participants communicated that they perceive their firms as an entity with full BIM implementation.

This highlights that a small portion (20%) of the selected participants perceive themselves as employed in a company with full BIM implementation. This provides the notion that is focusing on BIM related strategies in the proposed solution package may not be viable at the current stage. This is since a full BIM implementation need to take place for the strategies to function with full effect. Rendering most of BIM related strategies unemployable due to the absence of the framework for its application. Therefore, shifting the focus of the solutions package that will be proposed from being BIM focused to be knowledge management (KM) focused.

The reasons for different levels of BIM implementation communicated within the survey by the participants in section 7 are summarized as the following:

- The belief that what has been working in the past will continue to work in the present therefore there is no motivation to change.
- Local requirements by government bodies such as Dubai Municipality.
- Lack of awareness of BIM's potential benefits.
- Absence of experienced staff who can lead and operate the BIM process within the project.
- Cost associated with the migration from 2D CAD to BIM including software cost and operators' cost.
- Client requirement.

Furthermore, the survey indicates that over 77% of the participants believe that the information related interfaces between entities with different level of BIM implementation will induce rework due to various reasons.

# Chapter 6: Discussion

There seems to be a lot of causes which leads to rework as discussed in the previous chapters; the literature review chapter highlights that there two main categories of rework inducing factors consisting of factors related to design changes and factors that are contributing to nonconforming physical execution onsite. The design changes factors are divided into two sub-categories which are internal consisting of design related, contractor related, client related and project related.

The design related design change factors include poor communication between the client, the consultant, the sub consultants and the contractor. Moreover, lack of expertise, outdated construction technologies incorporated in the design, additional and unplanned design load, results of over competitive bidding by the consultants, misalignment between the commencement of construction activities and the readiness of information and not involving suppliers and subcontractors early on in the project are other design related factors.

The contractor related design change factors include preference to use local materials, modification to the construction methodology or sequence for financial or simplification purposes, rectification of construction mistakes and errors which may be extended to virtual design change, insufficient use of information technology and insufficient skills and workmanship levels.

The client related design change factors include changes in the design intent or requirements, poor design brief preparation, financial problems, both indecisiveness and insistent nature, poor attention to site conditions, limited involvement in the project and assigning low design service fees for the consultants.

Project related design change factors include project location, accessibility and underground conditions.

The second sub-category of factors which causes design changes is the external factors which includes local codes and regulations, interface with service authorities and providers and the environmental, economic and political context around the project.

The second category of rework inducing factors are the ones which would result in physical execution that is not conforming to the design or quality standards. These factors include limited access to the latest information by the operations teams, lack of experienced labor force, project budget pressure, poor quality of information, activities running out of sequence due to lack of discipline, lack of resources, poor or lack of planning, poor quality implementation and support, poor managerial qualities and failure to learn from previous mistakes.

These factors were filtered and combined in order to facilitate the evaluation of their importance through a survey which was discussed in Chapter 5. Participants' responses are summarized in Figure 58 below.

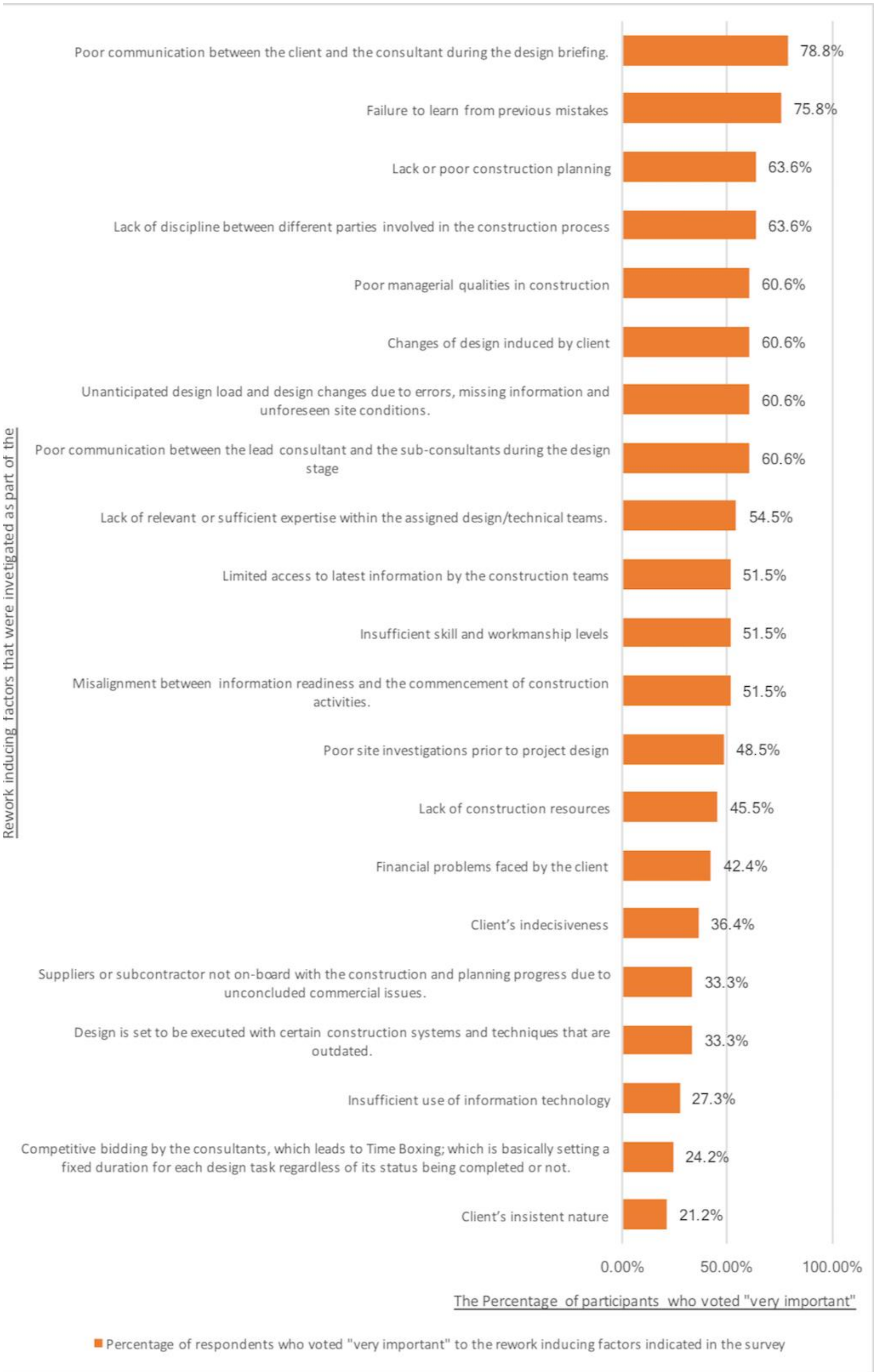


*Figure 58: Percentage of respondents who voted "very important" to the rework inducing factors indicated in the survey*

Furthermore, and as discussed in Chapter 4 of this research, a case study analysis was conducted highlighting both rework preventing and causing events and actions and their impact of the overall project's performance, these events and actions were identified by the author as direct observations. These observations include the employment of specialized and dedicated quality control teams within a project, implementation of benchmarking system within the project, implementation of construction planning and tracking system (LOB), implementation of Area Access Record (AAR) system and on-site deign development.

The employment of quality control teams can aid significantly in reducing rework as they would establish, implement and monitor the standards and procedures of construction activities. However, their input should be valued by the management teams on site where focus should be shifted from quantity performance to quality performance. Otherwise, their role will only be viewed as an obstacle to work progress and not as an essential factor in handing over a satisfactory project.

Implementation of a benchmarking system in a project can help reduce rework by the completion of a portion of the project to its final state. This will provide a finished portion of the product that will be provided to the client. Aiding in managing the client's expectation as it would give a realistic image of how the final product is like. Furthermore, it aids in highlighting and resolving unaddressed details within the design. This would ultimately allow the client to identify any features in the design that are not satisfactory and which were not picked up in the drawings. Therefore, should the client issues a site instruction requesting to change a certain feature in the design, the impact won't be as significant in comparison to issuing the same in a later stage of the project where a greater sum of the work had been completed.

Construction planning has proved to be a significant tool in determining what are the activities and in which sequence they need to be organized in order to achieve the most optimum path of progression to deliver the project. Occasionally, if an activity is carried out in a nonconforming manner, time and resources will have to be dedicated to rectify the nonconformance. Such allowances of time and resources usually are not part of the plan in the first place which would cause the balance activities to “squeeze-in” to allow for that rectification to take place. Ultimately resulting in an applied pressure on some if not all of the balance activities which can be a cause of rework.

The Area Access Record system can impose a significant level of control on the activities that take place on site. This can take place by displaying the status of work as in where each team is working compared to where they are supposed to be working to the management teams. Furthermore, it can highlight any out of sequence activities for the management to stop and eventually prevent. This will result in reduced rate of rework due to out of sequence activities. However, the manual labor of following the status of each zone and taking care of handing over the access record form one team to the other can make the process tedious. This will result in low efficiency and performance increasing the possibility that rework or even halt the progress of the work will occur because the system isn’t functioning properly.

Poor contract documents provided by the client/consultant has resulted in an epidemic practice of developing design on site which is usually carried out by the contractor. Such processes may induce both virtual and physical rework as the intention of the design by the consultant may not be fully transmitted to the contractor to carry out the design development properly. Furthermore, the contractor may develop the design by filling the gaps with details that are only code compliant but may not be of a satisfactory performance or aesthetics to the client. Forcing the client to issue Site Instructions which would cause further rework.

The contractor being part of the construction group plays a significant role in identifying and reducing rework by attempting to create solutions which would vary in its nature. Knowledge related issues have proven to be one of the root causes of rework in construction and solutions to manage them can help significantly in improving the construction industry. Therefore, this research will discuss potential solutions or improvements for the issues that were discussed in the previous chapters. These solutions and improvements would constitute the package of which this research will be offering within its scope. The causes of rework that will be addressed as part of this research are the following:

*Table 3: Issues that induce rework which are related to information processing and management*

| No. | Issues inducing rework which are related to information processing and management |
|---|---|
| A | Unanticipated design load and design changes due to errors and missing information. |
| B | Time boxing; which is basically setting a fixed duration for each design task regardless of its status being completed or not. |
| C | Misalignment between information readiness and construction activities. |
| D | Poor quality of information. |
| E | Lack of discipline (working out of sequence). |
| F | Limited access to latest information by the construction teams. |
| G | Rectification of construction non-conformance and errors. |
| H | Insufficient use of information technology. |
| I | Failure to learn from previous mistakes. |
| J | Lack of awareness of the scope of work of each entity within contractors and subcontractors. |
| K | Missing and inaccurate information in the design documents (contract docs and construction shop drawings). |

The sources of the solutions to the abovementioned rework causes would originate from further literature review along with author's proposals based on his experience within the construction industry; both of which will be addressed in this chapter.

## 6.1. Enhancing the construction planning procedures to reduce program slippage impact in inducing rework and enhance the efficiency of the construction process:

Construction planning is defined as creating the right sequence to enhance performance during project execution. Planning in construction is usually divided into two main types, strategic and operational. The strategic planning consists of the selection of the project's objectives such as scope, procurement ways, scheduling and financing options, this is done by the creation of a preliminary framework of what to do and how to do it. Operational planning basically identifies each activity that needs to be done within the project's scope, it is characterized of being more detailed than the strategic planning and in providing a clearer idea of the required resources. (Minikevicius, 2016).

Many construction planning methodologies exist today which have different advantages and disadvantages. One of the most commonly used methodologies is the Critical Path Method (CPM) which is introduced in chapter 4. This system provides an oversight of when a certain activity should start on site within a predefined construction sequence. The sequence within CPM incorporates the shortest path to obtain project completion. (Clough , et al., 2015). It plays an important role in providing necessary information for decision makers, provides the required information for time scheduling of construction, guide the contractor in find the shortest construction duration and aids in predicting resource requirements (Clough , et al., 2015).

CPM has two main phases which are the project planning phase and the scheduling phase. The project planning phase includes the identification of the primary items which facilitate project completion, identifies the sequence that these items should be carried out and providing a graphical representation of this information in the shape of a "network schedule" which would establish what is known as the job logic.

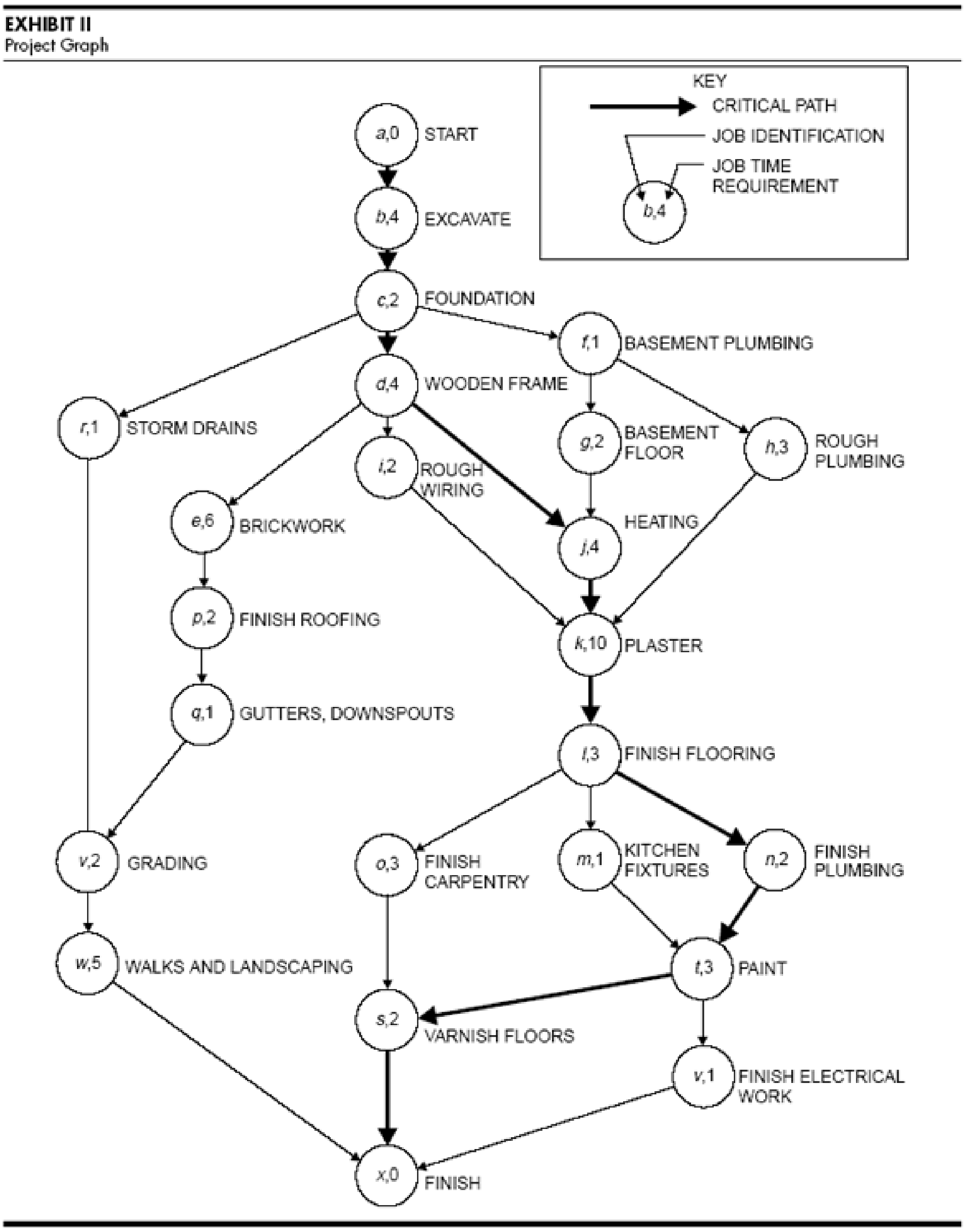


*Figure 59: Project Graph as a graphic representation of the critical path (Levy, et al., 1963)*

The scheduling phase identifies the time required to complete the project (refer Figure 58); this happens through the identification of the time required to achieve each activity or item and incorporating that into the network schedule (Clough , et al., 2015).

CPM is usually coupled with another graphical planning system known as the line of balance (discussed in chapter 4). This integration works best with high rise projects where there are repetitive floors but can also be utilized in horizontal developments. The integration works by dividing the project by floor or zone where each of these areas will have its own micro CPM plan. As discussed earlier, this plan will highlight when each task or activity will start as per the job logic which will help significantly in managing the work force and track progress. For example, there will be a number of teams who execute different activities in a high-rise project simultaneously. An example of a hypothetical project would have the structural team at floor X where rebar is being fixed in preparation to concrete pour, floor X-1 has no access for activities as the probing which supports the formwork of floor X is in place, the surveying team is at floor X-2 taking as built measurements of the structure and doing marking for blockwork activity, the masons team is at floors X-3 to X-5 erecting blockwork walls, MEP teams are doing their pre-bracketing activates (including marking and drilling) in floors X-6 to X-7, other MEP teams are installing brackets for their ceiling equipment and services at floors X-8 to X-10 and are doing their second fix (the installation of the equipment and services) in floors X-11 to X-13, the fit-out teams are installing ceiling grids in Floors X-13 to X-15, etc. The graphical description of the above is usually displayed as the Line of Balance diagram (Refer Figure16 in chapter 4).

However, CPM lacks to highlight the particular planning process for the activity itself in terms of information availability, resource availability, material delivery, access, etc. Moreover, it lacks the different entities' commitment to subtasks and more importantly it doesn't actively promote the awareness of the task's presence. Therefore, a planning system which addresses these aspects needs to be introduced.

The solution should be able to achieve three main objectives. The first objective is to be able to divide activities into smaller tasks which would need to be finished within the predefined duration in order to achieve required progress. The second objective is for the system to be able to identify upcoming tasks in the near future and communicate it to different relevant entities. The third objective is for the system to plan the preparation stage of the task ensuring everything related to the task is in order, resulting in proper and timely execution. The author suggests to utilize a planning system known as "The Last Planner" (LPS) (refer Figure 60). The proposed system would aid in increasing the reliability of the overall planning process in construction project delivery. This can be achieved by implementing the system's elements (Ballard, 2000).

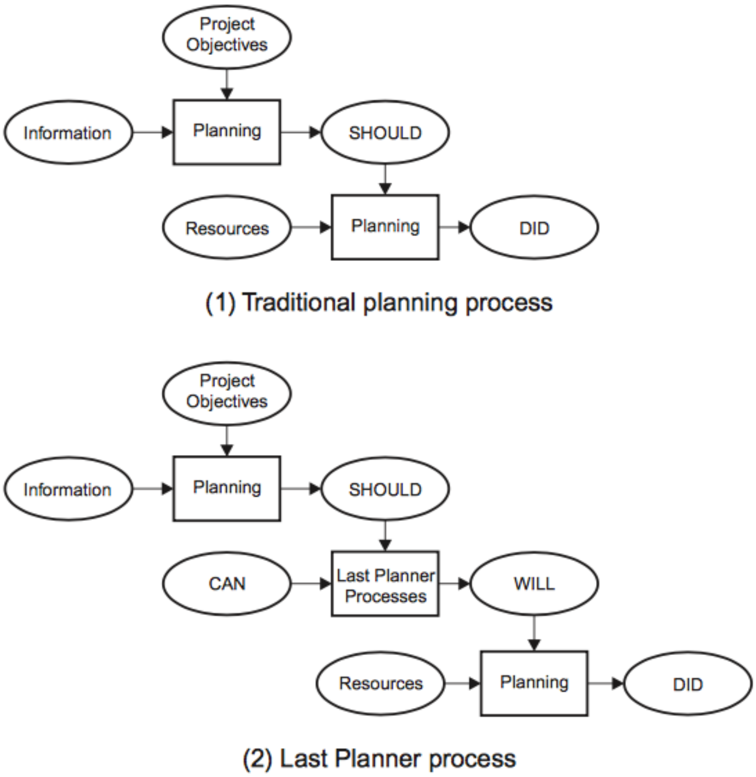


*Figure 60: Difference between traditional planning processes and the LPS (Kim & Jang, 2005)*

LPS has five main elements, the first of them is Master Planning where different teams collaborate, create and agree on a delivery sequence. This will help in identifying, discussing and agreeing on all interdependencies between different parties. Furthermore, it would aid in both the justification and the confirmation of the viability of the prediction that a project would be delivered on a certain date (Ballard, 2000).

The second element of the system is known as Phase Planning. The intent behind phase planning is to break down the master plan into smaller phases. Each phase can thereafter be detailed in way that clearly identifies goals for relevant entities (contractors, suppliers, sub-contractors, etc.) (Ballard, 2000). The benefit of identifying the goals within phase planning is to allow participants in achieving a certain goal the opportunity to properly assess and study the requirements to be fulfilled to achieve this goal.

The third element of the LPS system is known as the Look Ahead Planning. The intent behind this element is to plan the work to achieve a certain goal so that execution is ready to be carried out when it is due (Ballard, 2000). The difference between phase planning and look ahead planning is that the latter is more of a mid-range planning compared to phase planning which addresses a longer period that is shorter than the master plan. Planning for a certain time ahead helps bring focus on upcoming goals and aids in triggering actions in the present that would make the goal in the future achievable. The actions taken in the present to aid in the completion of a future goal is known as the Making Ready process. The actions within the making ready process plays a significant role in ensuring that the tasks which are associated with a certain goal are ready to be executed when due. This process will help in reducing waste of time, uncertainty and usage of both materials and equipment along with the benefit of highlighting potential constraints which may hinder the productivity. The look ahead process usually spans between 4-8 weeks (Ballard, 2000).

The Weekly Work Plan (WWP) is the forth element within the LPS system. It matches the master planning element by being collaborative. This collaboration usually happens on weekly bases between different entities concerned with the project. The WWP functions by assigning clear, properly sized and within sequence activities to relevant entities and ensures these entities buy into what is being assigned to them (Ballard, 2000). Moreover, the weekly collaboration helps share progress updates, plan the coming week and making ready for upcoming activities. This process will help to advocate for communication between different teams on site which will have an important impact on reducing rework on site.

The last element of LPS is the Percent Plan Completed (PPC). This element will help achieve continuous assessment and monitoring to productivity progress while adopting a “lessons learned” approach. This approach includes the analysis of the causation of tasks that are past their due and are incomplete. The result of such

approach is the improvement of the planning process overall as it absorbs the benefits gained from learning from previous mistakes. Furthermore, PPC can help shed some light on the areas that would require some development to achieve better overall results.
The percent plan completed is calculated as the number of the activities that are executed as per the plan divided by the total number of the planned activities then converted as a percentage.

The main perceivable benefits of the system are the quality assignments, the “can-do” approach and the analysis of errors and lessons learnt (Kalsaas, et al., 2009), (Ballard, 2000). The quality assignments mean that any work assignment should meet certain criteria before it is issued for execution. These criteria include proper definition, soundness, being within planed sequence and studied task size. This will significantly reduce uncertainty within the production teams as the process will help shield them from such constraints that may hinder the construction process (Ballard, 2000). This will help tackle issues A-F and reduce the potential of issue G from happening as part of this research’s scope highlighted in **Error! Reference source not found.**. Furthermore, and as part of the quality assignment procedures, the last planner usually assigns secondary activities which are characterized with lower priority. This will help to serve as a backup plan should the main assigned activity fail or halt for whatever reason. Moreover, this would help the teams who are exceeding expectations to perform more impacting positively on their PPC (Ballard, 2000).

Most of the popular planning systems such as the CPM employs the approach of a “should-do” approach, which usually works hand in hand with a reactive management style that monitors results. The LPS employs a “Can-Do” approach which differs from traditional approaches in two main features, the first being the shift in the management style from management by results to management by means, this will shift the focus from final results (whether in line with the program or not) to the evaluation of current progress trajectories against planned completion dates. This will change the management style from being reactive to a missed delivery date to being proactive in order not to miss a delivery date. Therefore, the remedial reaction from the management team to missing a planned date has now been changed to a preventive action to stop the delay from happening. This will result in a significant reduction in execution pressure build up (time pressure usually experienced by contractors during the late stages of a project). This is due to the fact that the pressure is being divided throughout the full duration of the project rather than being accumulated at the end of the project. This will help alleviate the impact of issue A & C significantly which are part of the rework causes highlighted in **Error! Reference source not found.**. The second feature of having a "Can-Do" a pproach is that during the look ahead weekly meetings, different entities can buy-in the assigned task in terms of agreeing to its importance, sequence, requirements and possibility of execution with current set of information, equipment, time and resources. Furthermore, it allows the same teams to refuse some assignments due to the aforementioned constraints. Such approach can significantly help reduce uncertainty in construction (Kim & Jang, 2005).

The third perceivable benefit of the system is the identification of constraints & errors during construction and the employment of lessons learnt in the construction process to improve productivity and efficiency. Such processes would not only aid in the resolution of problems and constraints but would also help anticipate them in the future and resolve them before they impact production. Furthermore, the last planner being the person with visibility on these issues can upstream their existence to the project planners to incorporate their impact should it not be avoidable into the master plan. This would provide a more realistic date of delivery and can help avoid point "I" during construction highlighted in **Error! Reference source not f ound.**.

Further to the previously discussed benefits of the LPS, the system actually has a certain overlap with the CPM planning system. This overlap is visible since the CPM system has an overall execution plan which is divided usually as per the areas of the project and as per the project's job logic. This shows common ground with the LPS system as the latter also employs a master plan for the overall project divided into phases. Hence, the LPS's phases can be considered as an equivalent to the CPM's Line of Balance areas or zones. Therefore, the major difference between the two systems in terms of structure is the look ahead plan, the weekly plan and the planned percentage completed. These three elements are what the author will include in the rework reduction package that would be offered as part of the scope of this research. This is due to the similarities identified earlier between the two systems which would make the implementation of the LPS easier as it is complimenting an existing system rather than attempting to implement a brand-new system altogether.

Furthermore, what needs to be noted is that there is a strong connection between the look ahead planning and the master plan. The reason for that is that not only will the master plan guide the sequence of the work by giving information of what needs to be done on a particular week, but it will also provide notifications on when would a long lead item need to be finalized and procured. This can further be triggered by the integration between the master plan and the procurement schedule which would contain product delivery durations. Thus, helping reduce productivity down time due to unavailability of materials or equipment.

A further enhancement to the system is the integration of a checklist system that would contain all required actions to finish a task. Therefore, a task will not be considered as done unless all required actions are done and checked. This will help shield the production in the following task. Moreover, this will at the same time prevent back flow in productivity progress where teams will have to revisit areas (or phases) that is supposedly have been handed over. Checklists can be developed to include both general and task specific required actions or even project specific should such needs arise. This will assist in reducing the impact on item “D” in **Error! Reference source not found.** on the construction process.

## 6.2. Enhancing design detailing and coordination during construction to avoid rework:

As discussed in the literature review within this research, design can play a significant role in inducing rework to the construction process as well as it can play a significant role in reducing rework in the same process. Therefore, and as part of the scope of this research, the design detailing and coordination processes that falls within the scope of the contractor will need to follow certain guidelines that should help boost its efficiency in reducing rework in construction. Items "C, E, F, J & K" in **Error! Reference source not found.** are to be impacted with this strategy to r esult in rework reduction.

Misalignment between information readiness and construction activities commencement can be reduced through integrating the information release schedule (IRS) of each discipline (as explained in chapter 4) into the proposed last planner system. The design process shall be considered as any other process in construction in terms of its requirements to time and resources. This will ensure sufficient care is taken in the detailing & coordination process before information is released to site. Therefore, aiding in increasing the quality level of the produced information (Item "D" in **Error! Reference source not found.**). Through knowing t he activity starting date and the IRS duration, the last planner can identify the IRS commencement date, track its planned progress and identify information release date.

Design work out of sequence usually leads to virtual rework as prerequisite information wasn't available when the work has started therefore impacting the design activity outcome. This will force the designers to adopt the latest available information (which is usually the contract documents) in developing their design which may not capture latest information from other contractors or subcontractors. Therefore, information flow direction (who should hand over information to who) and timing (when should information be passed on the following entity) should be controlled to avoid rework. Such objectives can be achieved through the implementation of a Design Deliverables Schedule (DDS) which should include the following:

1. A clear picture of where the detailing of any element can be found in the construction documents and drawings and who is the entity responsible to develop and deliver this detailing.

2. A clear sequence of information handover which takes into account the requirements of each entity to produce the entity's design deliverables.
3. A clear indication of the planned submission date of each design deliverable.

This will result in improved design planning process as all design deliverables can be identified and to some extent can be measured. This aids in reducing the impact of items "A-E & J-K" in **Error! Reference source not found.**. Furthermore, the D DS can help act as a checklist which can be integrated into the proposed last planner system. This integration will help shield the virtual production of design detailing of the next entity, this can be achieved as the DDS will act as a check point to ensure that the existing entity has developed and executed their detailing based on the latest base information (whether its contract documents or shop drawings from other entities). Therefore, the main benefit is that the last planner will not allow virtual or physical work to progress unless relevant prerequisite virtual and/or physical activities are concluded.

Contract documents forms a significant part of the project's design which includes issued for construction drawings and specifications being the base information from which detailing will progress. As discussed in the literature review chapter, poor construction documents can lead to both physical and virtual rework. The same was validated in the questionnaire within this research. The impact of poor contract documents will gradually increase during construction as work is progressing on inaccurate and/or mis-coordinated information. Therefore, the requirement to appoint an experienced technical team to evaluate the contract documents is crucial. This will help highlight, record and resolve any discrepancies, nonconformance or errors in the design. Thus, alleviating the pressure posed by item "A" in **Error! R eference source not found.**. It's important to highlight that this goes in line with one of the last planner's core values which is shielding the production lines (both virtual and physical) from immature or inaccurate information. The resolution of discrepancies, nonconformance and errors can take place thereof by raising request for information documents (RFI) and through design workshop meetings.

The other source of base information that must be evaluated and paid attention to is the information exchanged between different design entities within the main and sub-contractors. This information is usually issued as shop drawings or 3D models to provide base information for other entities and at the same time obtain consultant's/client's approval on the same. This is where a shared design coordination platform between different entities plays a significant role. Since 3D coordination exercises and clash detection management are slowly becoming the norm in the construction sector, such practice will help increase the efficiency of the coordination process as the project is being built virtually before it gets executed on site thanks to platforms such Autodesk Revit. Such virtual structures are then evaluated virtually in terms of their spatial coexistence in platforms such as Autodesk Navisworks. Thus, reducing the impact of item "H" within **Error! Reference source not found.** in inducing rework to the construction process. Failure to maintain such common environment between project's stakeholders can significantly hinder the coordination process and help induce rework as concluded in the result of the questionnaire carried out in the scope of this research.

As the information is flowing through different entities, any change in the information provided by one of the entities will have an impact on the information produced by the ones that will follow. Therefore, it's important to set up a list of requirements within the DDS communicating all prerequisites to finish certain design deliverables. This will allow all entities to understand the level of quality of the information that is being communicated to them which they would use as base information for their design deliverables.

Furthermore, using the latest information produced by the previous entities as a base plays a significant role in determining the quality level of the information produced by the current entity. Moreover, should there be a change or revision in the information provided by one of the information providing entities, this change can have an impact on the quality level of information and potentially all the information released by proceeding entities. Therefore, a certain dependency system between the information released by different entities needs to be established. This will work as a notification to the user who would access a shop drawing for example that the base information has been updated. This can be stated as a precaution to the user alerting him not to proceed. Resulting in preventing execution based on incorrect information therefore reducing physical rework.

The DDS will play a significant role in preventing such incidences from occurring as it will clearly highlight the dependencies among different entities with regards to information. This dependency can help the document controllers identify which drawing is based on what base information (other drawings). Therefore, the document controllers can manually highlight the impacted released information as well as the information which is under process. Furthermore, they can notify the operation teams that the information needs to be updated and are not to be followed. This is until the author of the information confirms that the update in the base information have no impact or until the base information and the design deliverable is updated all together.

Such task for the document controller can be tedious as a lot of drawings are submitted and resubmitted daily in a construction site. Therefore, depending on manual identification may not be very reliable. Furthermore, existing information management platforms such as ACONEX for example doesn’t incorporate such facility within their platform. The closest platform to this facility is BIM360 DOCS which allows the user to compare between two different versions of the same document (ie a drawing or a BIM model) but it doesn’t address the dependency issue. However, BIM 360 Docs employs a certain technology known as Optical Character Recognition (OCR) which basically aids the system in identifying the information inserted within the title block of a submitted drawing. This aids in automatically filling in the information of the drawings such as its name, reference number, revision, etc. rather than inputting them manually by a document controller in the system. This feature can be developed further to be able to read the reference information a drawing is based on which is usually indicated within the title block of a released drawing. Therefore, any update in the base information can automatically be identified since it is within the same platform. Furthermore, this can be integrated with an automated notification system which basically sends a notification to the author that certain base information has been updated and may have an impact on the design deliverable. Furthermore, this notification can be also circulated to “users” alerting them that the shop drawing they are using or its base information needs to undergo a revision. Therefore, the change needs to be clarified and addressed for work to proceed. This will ensure that everyone is working of the latest information which incorporate different stakeholder’s requirements along with maintaining high levels of accuracy.

Quality requirements for submitted information shall include the following:

- Approval is obtained from relevant parties (such as consultant, sub-consultants and clients)
- Approval from the representative of the technical team of the entity to confirm the quality of the information. The quality includes being in line with the contract documents and all information related documents produced up to the date of issuing the information such as RFIs, Engineer’s instructions, Site instruction, etc. Moreover, quality of information also includes the confirmation that all references for base information has been indicated on the drawing. This is because the document controllers or the proposed system won’t alert a change in a base information if the reference of the base information was not mentioned in the submitted drawing.

The utilization of such information management platforms can help reduce rework and waste by alleviate the impact of items A,D,F,H& K from **Error! Reference source not found.**.

What needs to be noted here is the fact that both the IRS and the DDS depend on the transition of the state of certain design objects (such as a shop drawing) in time. This is due to that fact that whatever is shared to any party should be submitted to the consultant for approval or at least extracted from approved information. However, most consultants are not equipped to handle an alternative and more dynamic information communication forms such as a BIM model compared to shop drawings which prevents its usage. This has to do with the fact that BIM is a rather new tool compared to conventional information communication methods in construction. Therefore, since a snapshot of the design is usually released to the consultant for approval, this same snapshot is being circulated as base information for other parties within a construction project once it is approved. The submitted snapshot within these drawings should always reflect the latest revision to the design. This is due to the fact that the contractor usually won't be compensated for his work should installation proceeded in a different configuration from the approved shop drawing. Therefore, the contractor should always ensure the latest design information is submitted and approved by the consultant. However, common platforms for design & collaboration can still be implemented and governed by the IRS and the DDS under the main contractor's umbrella. Yet, it won't be dynamic unless this dynamicity is extended to the approval process as well.

The above highlight a potential problem with regards to the coordination/approval process when there is an upstream of information during coordination. For example, contractor A has finalized his design and has submitted it to the consultant, obtained approval and issued it to the proceeding contractor to use the same as base information. In the event where the proceeding contractor faces a problem in coordination with the received base information, he would require the preceding contractor to modify his design. Yet the preceding contractor has already submitted his drawing for review by the consultant which would be a rework. Moreover, the relevant materials could be procured as per the approved shop drawings by the first contractor or even installed on site. This causes the design to arrive at a bottle neck where compromise should take place by either contractors or the client.

It would seem that such scenarios can be avoided through the implementation of information package submission per zone (a package for one apartment type in a residential tower for example). Such approach would allow information to travel freely between all contractors for a certain zone to allow for primary coordination. Thus, allowing each contractor to identify his constraints and communicate such constraints to other relevant parties. Thereafter, when full coordination is done for a zone, a full set of drawings would be submitted to the consultant for review inclusive of all disciplines.

The problem with such approach is the fact that such activity can take a significant amount of time for it to be concluded. Furthermore, it doesn't go hand in hand with how sites usually progress as physical activities can't all start at the same time once approval is received. Therefore, forcing the first physical activity to start after the approval of the last's activity shop drawing of a particular zone. In contracts, should shop drawings be submitted by discipline, a trade (rebar for example) can proceed once the relevant shop drawing is approved despite the fact that there are other drawings (ID Flooring layout for example) for the same zone still being developed. The issue with this approach is that should the flooring layout derive the relocation of a floor drain in a wet area for example, this will lead to both virtual and physical rework by the structure technical and operation teams to incorporate this change. Which constitute more rework in comparison to the information package submission coordination work flow discussed earlier.

Furthermore, it would be very difficult to differentiate in submission between elements that are relevant to particular zone (the reflected ceiling plan of a flat for example) and other items that require a more macro review (building elevation for example). Therefore, due to the complexity of such approach and the time requirement such strategy requires, it will not be considered within the proposed package of this research.

Due to the impracticality of the strategy discussed above, contractors usually stick to contract document information should developed information and approval is not available to allow the physical activities to start, then the level of rework becomes dependent on the level of coordination that the contract documents possess. Therefore, rework cannot be fully avoided unless project construction duration is extended or full coordination is ensured in the provided contract documents.

What needs to be noted also is that there is a certain level of unavoidable rework when it comes to design. This is since a certain base information has to be present for a second party to build upon and coordinate with. Which may result in an information upstream should the there be a need to change the base information. Therefore, virtual rework is not completely avoidable.

## 6.3. Enhancing construction management strategies to avoid rework:

Managing construction activities on site and maintaining discipline and alignment to job logic and sequence plays a significant role in reducing rework as discussed in chapter 4 & chapter 5. One of the main causes of rework that is caused by improper management is out of sequence work. The cons of out of sequence work have been discussed in chapter 4. Chapter 5 discusses a solution for out of sequence work which is the implementation of an "Area Access Record (AAR)" system which records each activity that happens in a zone. This system works by having a document that represent the status of a certain zone within a project. The ownership of this document represents the sole access right to that zone. Any sub-contractor will be penalized should they access a zone for work without owning its AAR. Therefore, the AAR handler will furnish the AAR to the sub-contractor whose work should commence as per the project's planned sequence, this will take place after the quality control team has signed the AAR document accepting the work of the previous subcontractor. The current subcontractor will maintain the ownership of the AAR document until his work is concluded and the quality team has accepted the subcontractor's work. Afterwards, the AAR will be returned to the AAR handler where he will update the project's AAR log accordingly and pass on the AAR to the next subcontractor as per the planned sequence.

The implementation of this system in the case study project faced difficulties due to the absence of a dedicated team or person who oversees and takes ownership of this process within the project. The fact that there are multiple activities that are taking place simultaneously whether starting or ending has proved to make the process labor intensive. Furthermore, and due to the fact that this process isn't significantly implemented within the contractor's organization, the process for tracking the AAR had to be done manually where a person within the main contractor organization had to joggle multiple AARs between several sub-contractors. Furthermore, the handler would have to update a register which reflects the status of the overall project. This posed significant load on the personnel who was carrying on this task besides his daily duties which caused the system to lag behind the actual site condition and in some cases, halt the site production.

The solution proposed within this research is to automate the AAR system by creating an online platform where different sub-contractors' representatives can log in and update the AAR status of each zone under their control. This will eliminate the requirement of a middle man who would manually track and update the AAR. Furthermore, this will help demonstrate a live update of the status of the project at any given time of the project's duration to the management to aid in decision making and alert them should there be any delay in work progress.

The automation will work by providing each representative with a unique username and password which would be the equivalent of their signature on the AAR document. Once the work is done in a certain area, the representative can offer the area for inspection within the platform to the quality control team. Once the work is approved by the quality team, the area's AAR ownership gets transferred automatically to the next in sequence subcontractor while updating the AAR register in the process. The next subcontractor will receive an automated email informing them that the area is now under their control for them to commence their activities.

The AAR system can help improve the progress monitoring of a project as the planners can easily identify what is the status of each zone and compare that to the planned progress of that zone. This will help highlight any areas in delay to the project's management to take a remedial action. The implementation of such platform can help reduce rework and waste in a construction site by reducing the impact of items E,G,I& J in **Error! Reference source not found.**.

## 6.4. Enhancing construction execution through lessons learned:

The first aspect of lessons learned is discussed in chapter 4 highlighting the benefit of benchmarking in construction projects. This includes the creation of a mock up that will help serve as a prototype which will demonstrate the final result as per the contract documents to the client. Furthermore, it will help to serve as a reference for further work within the project itself especially if the project consists of multiple zones with similar characteristics (an example of a mock up apartment in a high-rise residential building).

The implementation of the benchmarking system will help better manage the client's expectations by constructing a portion of the overall project that is more or less representative of the rest of the project. Furthermore, it will help in identifying any misconceptions between the client's and the contractor's interpretation of the contract documents, providing an opportunity for both parties to discuss any issue concerning the mock up and reach to an agreement prior to continuing with the overall execution. Moreover, this will help identify any flaw in the design which wasn't picked up in the detailing process of the items of the mock up. This would help reduce the potential of massive rework due to change orders caused by impracticality of design, execution or client's preference in comparison to redoing a single instance of a certain repetitive item in a project. Such strategy will help reduce rework and waste but managing the impact of items A,D,E,G,I,J& K from **Error! Reference source not found.**.

The other aspect of lessons learned is the creation and maintenance of a construction knowledge data base which would contain various types of information. This information includes standard execution and coordination procedures, typical design detailing and related documents of typical items, construction checklists, etc. This will significantly help reduce rework in construction projects, both virtual and physical.

An example of the benefit of such databases is the approval process required for a typical item such as steel bollards, the location and quantity of the bollards are governed by the contract drawings of a project yet their performance criteria is usually in reference to recognized international standards. Therefore, the structural calculations that demonstrate the alignment of the performance of the steel bollards to the relevant international standards can be maintained in the construction database along with their typical detail. Therefore, it will be easily accessible to future projects in the attempt to ensure accurate coordination with other trades by identifying relevant requirements of the item even before the appointment of a supplier for the same by the main contractor.

Furthermore, the database can contain challenges that were faced by the contractor in previous projects which would assist in identifying the same challenges in current projects and eliminate or at least minimize their impact. For example, it was identified in a previous project that cracks were appearing in wall plastering on areas where there is an interface between two dissimilar materials such as concrete columns and blockwork, the problem was resolved by the introduction of a mesh coil that would bridge the joint between the two materials which would be imbedded in the plaster. Obviously in that project there would be a certain level of rework in removing the cracked plaster and replacing it with new plaster and coil mesh, whereas in a current project and due to the availability of such information from the data base, coil mesh was provided in all relevant areas which helped in avoiding rework and material waste.

Moreover, such databases can grow to become publicly accessed sources that documents challenges and obstacles that are faced on construction sites. Additionally, these sources can actually clarify how these challenges were addressed and resolved. This can also extend to the input from external professional bodies or individuals to provide a more rounded approach to tackle the said challenges.

This body of knowledge will work as a barrier that would protect projects from rework as it will not only point out the relevant challenges that could be faced during a project, but it will also provide a rounded solution that can be followed on site. This will help tackle two main issues that are considered extremely critical in construction projects due to their significant impact on the projects duration and / or work pressure buildup. The first is the elimination of a trial and error cycle to help find out what would work on site. Secondly, it is the reduction in the time consumed by the technical departments in their attempt in resolving a certain challenge as the solution is already provided within the platform. Resolving these issues can significantly help reduce rework caused by both time pressure and wrong execution. This will help alleviate the impact of points A,B,C & I from **Error! Reference source not found.** on the construction process helping reduce rework and waste.

The main challenge that would prevent such idea from taking place is the willingness of construction team members to take the time and record any relevant challenges and input the sort of the challenge, its causes, its constraints and how it was tackled. Such input is considered to be the backbone of such data base as any individual who is not part of the site or technical team won't have a clear idea on the challenges faced on a certain project, but may contribute to the resolution of a challenge should its nature, context and constraints are clearly communicated.

## 6.5. Summary:

Each of the proposed solutions discussed within this chapter has proposed a method to reduce the impact of the issues in **Error! Reference source not found.** in incurring both rework and waste in construction projects (summary of the same is illustrated in Table 4 below).

Each of the solutions was explained in a manner that is relevant to existing construction conditions and constraints here in UAE. Furthermore, relevant modern techniques have been incorporated to cope with the demanding needs of the construction sector. Below table illustrates the summary of the interface between the issues identified in **Error! Reference source not found.** and the potential solutions for them.

*Table 4: Summary of the interface between the proposed strategies to reduce rework and its identified causes highlighted in Table 1*

| **Proposed strategies to reduce rework** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| The last planner system: Quality assignment of tasks | √ | | | | | √ | √ | | | | |
| The last planner system: “Can-Do” approach | √ | √ | √ | √ | | | | | | | √ |
| The last planner system: Lessons learned | | | | | | | | | √ | | |
| The last planner system: Checklists | | | | √ | | | | | | | |
| The last planner system + Information release schedule | | | | √ | | | | | | | |
| The last planner system + Design deliverables schedule | √ | √ | √ | √ | √ | | | | | √ | √ |
| Contract document review and validation | √ | | | | | | | | | | |
| Implementation of latest information technology | | | | | | | | √ | | | |
| Enhanced information management platform | √ | | | √ | | √ | | √ | | | √ |
| Construction management: Automated area access record | | | | | √ | | √ | | √ | √ | |
| Benchmarking | √ | | | √ | √ | | √ | | √ | √ | √ |
| Construction information databases | √ | √ | √ | | | | | | √ | | |

As part of this research scope, these conclusions will be offered for evaluation and criticism to industry professionals for feedback. The method of this presentation, its extent and resulted feedback is illustrated in the next chapter.

# Chapter 7: Interview design and analysis

This chapter will discuss the design of the interview that will be conducted as part of the scope of this research. Furthermore, it will provide a summary of the outcomes of the same and present it as the final product of this research. The interview scope will attempt to provide critique to the knowledge management/rework reduction strategies proposed in chapter 6 of this research. The feedback from the interview either will confirm or nullify the benefit of the proposed strategies.

## 7.1. Interview design and selection:

As discussed in chapter 2 of this research, there are multiple types of interviews in terms of their methodology and desired outcome. In order to determine what type of interview to go with to best satisfy the requirements of this research, the outcomes of the interview should be identified.

The objective of the interview is to obtain criticism on proposed methodologies and strategies of knowledge management that reduce rework in construction. the outcomes would be the opinions of the interviewees with regards to the performance of each strategy against its specific intended objectives. Since the methodologies along with their objectives have already been identified, this suggests a reasonable structure for the interview.

Moreover, as part of validity checks for interviewee's responses, justifications for the stated responses will be requested to ensure their understanding of the methodologies and the objectives. Achieving that aspect in the interview will require certain flexibility in the interview's structure to allow the interviewees to elaborate more on why they agree or disagree with what is proposed.

In light of the above, the interview type should be able to accommodate a mixture of structure to cover all the proposed methodologies as well as provide certain flexibility to provide the interviewees a certain level of freedom to express what they believe. Therefore, the selected interview type would be a semi-structured interview.

The interview will evaluate the methodologies identified in **Error! Reference s ource not found.** against rework causes concluded in Table 4**Error! Reference source not found.**. The interview was piloted with one instance to ensure clarity of requirements and aid in understanding any shortcomings or obstacles. The pilot interview provided the following insights:

- There is a possibility that the interviewee is not fully aware of the systems and ideas that are being implemented (such as The Last planner, Area Access Record, etc.). Therefore, an introduction to the terms used within the interview needs to be clarified and defined prior to asking the interview questions.
- The attempt to validate that a strategy achieves its anticipated objective and confirm it doesn't satisfy or is not applicable to other objectives as per **Error! Reference source not found.** has proven to be time consuming (due t o this aspect, the pilot interview lasted for around two and a half hours). This proved to be challenging and can impact the quality of the answers provided. Therefore, the design of the interview needs to be optimized to shrink the interview duration and keep the interviewee engaged.
- The strategies suggested vary in effectiveness when they are implemented in isolation compared to when they are cumulatively implemented as a package. An example would be the benefit of the last planner combined with lessons learned, the interviewee in the pilot interview believes that this strategy can limit rework but can't prevent it alone. However, should the above-mentioned strategy is implemented alongside the construction knowledge database strategy then the last planner can identify the potential

error from the data base. This will help the last planner prevent a first instance error in the project. Therefore, avoiding rework.

In order to address the above-mentioned constraints within the interview design, the following solutions were utilized:

- The terms discussed within the interview will be defined in a handout that will be provided to all interviewees prior to the interview. The author will ensure that the interviewees are comfortable with the terms before starting the interview utilizing samples and visual representations when required.
- The duration of the interview shall be optimized by limiting the strategies' evaluation against only the objectives they intend to achieve as specified in **Error! Reference source not found.**.
- The strategies will be evaluated individually only against the objectives they are intended to achieve to reduce the duration of the interview.

## 7.2. Who will be interviewed:

There are twelve knowledge management / rework reduction strategies that are being proposed to resolve or at least reduce the impact of eleven factors inducing rework as part of this research. The attempt of the interview to capture all relevant inputs with regards to the same can be significantly time consuming. Moreover, giving the nature of the interview which allows the interviewees to elaborate on their response. The author believes that a lesser number of interviews but with more extensive responses is the appropriate path this exercise should take.

Furthermore, due to the nature of the solutions proposed being within the contractor scope, the author believes the interviewees should come from a contracting background as they will be more familiar with such processes and their applicability in such context compared to a consultant or a developer.

Therefore, the author will conduct the interviews with construction professionals who have contracting backgrounds. Furthermore, interviewees will represent the most important segments concerned with knowledge management / rework reduction. These segments include design, operations, management, planning and quality control. A construction professional from each segment will be interviewed for a total of five interviews as part of this research's scope.

## 7.3. Feedback from the construction professionals on the proposed strategies:

As discussed previously in this chapter, interviews with construction professionals will be undertaken to obtain feedback on the proposed strategies. This feedback will be utilized to confirm or nullify the benefit of the proposed strategies in reducing rework on construction sites. Construction professionals from contracting backgrounds with specialization in design, operations, management, quality control and planning will be interviewed as part of this research scope.

### 7.3.1 Feedback from construction professional with design background:

Table 5 below describes the interview conducted with a design related professional with contracting background. The interview was conducted on the 15th of May 2018.

*Table 5: Feedback from a design oriented construction professional with contracting background*

| No. | Challenges as identified in Table 3 | Solutions as identified in Table 4 | Yes/ No | Comments |
|---|---|---|---|---|
| 1 | Reducing unanticipated design load and design changes due to errors and missing information can be achieved by | 1.1 Quality assignment of tasks within the last planner. | Yes | Because it ensures prerequisite information is provided. |
| | | 1.2 Adopting a "can-do" approach within the last planner. | No | Information may not have the desired representation but can still be made in a way that is readable and useable for work to progress (such as a sketch rather than a fully detailed shop drawing). Such scenario is applicable especially if the delivery date of the information was set by the requesting party, not the authoring one. |
| | | 1.3 Incorporating design deliverables schedule with the last planner. | Yes | Because the execution party will be aware of the information production requirements which will aid in reducing inaccuracy of information. |
| | | 1.4 Contract documents review and validation. | Yes | This helps as we can ask for all missing information / documents before the requirement becomes critical and work has to be done with available information. |

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| | | 1.5 The implementation of an enhanced information management platform. | Yes | Because all information is easier to access and documents can be rectified immediately in case of any missing information. |
| | | 1.6 Benchmarking. | No | Because benchmark cannot be achieved without obtaining correct information. |
| | | 1.7 Construction information databases. | Yes | It provides access to information rather than creating the information from scratch. |
| 2 | Reducing limited access to latest information by the construction teams can be achieved by: | 2.1 Quality assignment of tasks within the last planner. | No | It takes quality information in the first place to issue quality assignment. |
| | | 2.2 Implementation of an enhanced information management platform. | Yes | It provides a single medium of information for all parties. |
| 3 | Reducing rectification of construction non-conformance and errors can be achieved by: | 3.1 Quality assignment of tasks within the last planner. | Yes | Because all requirements are being provided. |
| | | 3.2 The implementation of an automated area access record. | Yes | Because activities are aligned and sequenced. |
| | | 3.3 Benchmarking. | Yes | Because benchmark can give clarity on wrong or inaccurate details and assist in rectifying them. |
| 4 | Reducing time boxing can be achieved by: | 4.1 Adopting a "can-do" approach within the last planner. | No | Having a can-do approach doesn't mean that base information is correct which may end up increasing the duration of the time box. |
| | | 4.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | Because DDS allows you to be aware of / acquire all the information before deciding the time to carry out the activity. |
| | | 4.3 Construction information databases. | Yes | Provides access to information rather than creating the information from scratch which aids in the achievement of the time box duration. |
| 5 | Reducing misalignment between information readiness and construction activities can be achieved by: | 5.1 Adopting a "can-do" approach within the last planner. | Yes | by having a can-do approach, and being aware of time line and other required deliverables for other tasks that might be also important, your commitment to a deadline is improved. |
| | | 5.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | DDS will provide more awareness of the preceding activities required to carry on a task therefore help enhance the commitment |
| | | 5.3 Construction information databases. | Yes | Having access to information can help aid in achieving commitments and avoid information delay due to missing information. |
| 6 | Reducing poor quality of information can be achieved by: | 6.1 Adopting a "can-do" approach within the last planner. | Yes | As it allows planning and limits pressure which can create errors in production. |
| | | 6.2 Adopting checklists into the last planner system. | Yes | It adds quality to the work and ensures no missing information even if there is pressure to execute the work. |
| | | 6.3 Adopting design deliverables schedule incorporated with the last planner. | Yes | DDS will provide more awareness of the preceding activities required to carry on a task. |
| | | 6.4 Implementation of an enhanced information management platform. | Yes | Advanced information management technology with combined information in a single platform can significantly aid in enhancing the quality of information. |

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| | | 6.5 Benchmarking. | Yes | Information provided for the benchmark can be enhanced in reference to its physical execution. |
| | | 6.6 Incorporating information release schedule with the last planner system. | Yes | Because IRS allows planning and sufficient time to prepare the information. |
| 7 | Reducing missing and inaccurate information in the design documents (contract docs) can be achieved by: | 7.1 Adopting a "can-do" approach within the last planner. | Yes, | because the can-do approach will push the execution party to clarify any missing or incorrect information during production. |
| | | 7.2 Adopting design deliverables schedule Incorporated with the last planner. | No | Not relevant. |
| | | 7.3 Implementation of an enhanced information management platform. | No | Not applicable. |
| | | 7.4 The implementation of an automated area access record. | No | Not relevant. |
| | | 7.5 Benchmarking. | Yes | It will give clarity on missing or wrong information as the benchmark is a representation of a finished product. |
| 8 | Reducing lack of discipline (working out of sequence) can be achieved by: | 8.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | DDS will govern the sequence of activities which will improve discipline because of awareness of the sequence. |
| | | 8.2 The implementation of an automated area access record. | Yes | All works will be aligned with the schedule which is enforced by the AAR |
| | | 8.3 Benchmarking. | Yes | The benchmark will provide clarity on the most effective sequence of work. |
| 9 | Reducing lack of awareness of the scope of work of each entity within contractors and subcontractors can be achieved by: | 9.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | Because the schedule allows all the parties to have a clear picture of their requirements and scope of work. |
| | | 9.2 The implementation of an automated area access record. | Yes | All activities are aligned therefore this will enhance the clarity of scope between all parties. |
| | | 9.3 Benchmarking. | Yes | Since it increases the awareness of scope by all disciplines since they will have to execute it. |
| 10 | Reducing failure to learn from previous mistakes can be achieved by: | 10.1 The implementation of an automated area access record. | No | Not relevant as sequence of work is already defined. |
| | | 10.2 Benchmarking. | Yes | Because any mistakes in the benchmark can be a lesson learnt which can be avoided in physical execution in the future. |
| | | 10.3 Construction information databases. | Yes | The data base itself is generated as lessons learnt. |
| 11 | Reducing the insufficient use of information technology can be achieved by: | 11.1 Implementation of an enhanced information management platform. | Yes | It provides an opportunity for information to be explored more dynamically in comparison to old technologies |

The interviewee emphasized the importance of accessibility of information for all the parties relevant to a construction site. As this will expedite creation, review and approval of the said information which allow site to progress based on reliable information.

Furthermore, the interviewee also emphasized on the application of checklists in design deliverables. The creation of such filtration system will help both set the expectation of what will be provided as a design information as well as act as a barrier preventing uncoordinated information from reaching execution stage.

### 7.3.2 Feedback from construction professional with operations background:

Table 6 below describes the interview conducted with an operation related professional with contracting background. The interview was conducted on the 16th of May 2018.

*Table 6: Feedback from an operation oriented construction professional with contracting background*

| No. | Challenge | Solution | Yes/ No | Comments |
|---|---|---|---|---|
| 1 | Reducing unanticipated design load and design changes due to errors and missing information can be achieved by | 1.1 Quality assignment of tasks within the last planner. | Yes | Because the implementation of the quality assessments will reduce working loads as it filters tasks with incomplete information. |
| | | 1.2 Adopting a "can-do" approach within the last planner. | Yes | This is since a can-do commitment should involve knowing the current situation of a task and any shortcomings in its prerequisites. |
| | | 1.3 Incorporating design deliverables schedule with the last planner. | Yes | Since its absence can create errors or last minute changes due to absence of direction or requirements. |
| | | 1.4 Contract documents review and validation. | Yes | Obviously, such review will help identify any missing or unresolved information in the contract documents which will ease the shop drawings production load. |
| | | 1.5 The implementation of an enhanced information management platform. | Yes | As it becomes easy for operation to access information and reduce time for studying-before-execution which can help reduce errors. |
| | | 1.6 Benchmarking. | Yes | Its considered as a look ahead of the design. |
| | | 1.7 Construction information databases. | Yes | Assuming the information is in the data base, it can be accessed easily rather than produced. |
| 2 | Reducing limited access to latest information by the construction teams can be achieved by: | 2.1 Quality assignment of tasks within the last planner. | Yes | Because implementing quality assignments ensures latest information is present and ready. |
| | | 2.2 Implementation of an enhanced information management platform. | Yes | information is linked, Mismatch between different trades which is supposed to be coordinated is easier to be identified. |
| 3 | Reducing rectification of construction non-conformance and | 3.1 Quality assignment of tasks within the last planner. | Yes | Because latest information and sequence is already identified/provided in the quality assignment. |

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| | errors can be achieved by: | 3.2 The implementation of an automated area access record. | Yes | Because construction will be following a correct sequence that is agreed with all parties. |
| | | 3.3 Benchmarking. | Yes | As the benchmark is considered as a trial that is done ahead of program. |
| 4 | Reducing time boxing can be achieved by: | 4.1 Adopting a “can-do” approach within the last planner. | Yes | Because by having a can-do approach, you will have an understanding of the required time box. |
| | | 4.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | its provides more clarity on task’s requirements therefore allowing more accurate estimation of the required duration to carry on a task. |
| | | 4.3 Construction information databases. | No | The availability of information with the construction documents or the data based should already be factored into the task duration. Therefore, it will have no impact. |
| 5 | Reducing misalignment between information readiness and construction activities can be achieved by: | 5.1 Adopting a “can-do” approach within the last planner. | Yes | Because it provides vision for the operations to a potential missed target when the there is a reasonable absence of commitment which is the first step in avoiding a possible missed target. |
| | | 5.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | It provides vision on when information will be ready to allow the alignment or change in deliverables priority. |
| | | 5.3 Construction information databases. | Yes | As information can be obtained and not created. |
| 6 | Reducing poor quality of information can be achieved by: | 6.1 Adopting a “can-do” approach within the last planner. | Yes | The production team is being more realistic as right information requires time. |
| | | 6.2 Adopting checklists into the last planner system. | Yes | awareness of prerequisites and requirements improves quality. |
| | | 6.3 Adopting design deliverables schedule incorporated with the last planner. | Yes, | Provides clarity on the requirements and the prerequisites of each design task. |
| | | 6.4 Implementation of an enhanced information management platform. | Yes | Enhanced access to information can enhance information review reducing human error and therefore poor information quality. |
| | | 6.5 Benchmarking. | Yes | Its considered as a look ahead of the design. |
| | | 6.6 Incorporating information release schedule with the last planner system. | Yes | Because it acts as a reminder of what needs to be achieved. |
| 7 | Reducing missing and inaccurate information in the design documents (contract docs) can be achieved by: | 7.1 Adopting a “can-do” approach within the last planner. | Yes | Awareness of existing contract information is understood when committing to delivery. |
| | | 7.2 Adopting design deliverables schedule Incorporated with the last planner. | No | Not related. |
| | | 7.3 Implementation of an enhanced information management platform. | Yes | Enhanced accessibility to information can aid in the identification of errors and missing data in the contract documents. |
| | | 7.4 The implementation of an automated area access record. | No | Not related. |

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| | | 7.5 Benchmarking. | Yes | Since the benchmark is considered to be a finished product that is in a state which can be handed over to the final user where any missing items can be identified on site if not in the design. |
| 8 | Reducing lack of discipline (working out of sequence) can be achieved by: | 8.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | The DDS helps clarify the sequence in which design information should flow. |
| | | 8.2 The implementation of an automated area access record. | Yes | As it will work as a checklist and a reminder of the required sequence. |
| | | 8.3 Benchmarking. | Yes | As the benchmark is considered as a trial for the construction sequence. |
| 9 | Reducing lack of awareness of the scope of work of each entity within contractors and subcontractors can be achieved by: | 9.1 Adopting design deliverables schedule incorporated with the last planner. | No | DDS doesn't help identify items that have not been designed before. |
| | | 9.2 The implementation of an automated area access record. | Yes | Since the AAR is closed when all the activities list on it is completed. However, should there be a missing activity identified on site that was not represented in the AAR, this means that its scope was not awarded. |
| | | 9.3 Benchmarking. | Yes | Since the benchmark is considered to be a finished product that is in a state which can be handed over to the final user where any missing items can be identified on site if not in the design. |
| 10 | Reducing failure to learn from previous mistakes can be achieved by: | 10.1 The implementation of an automated area access record. | No | Not related. Because experience is not the same as lessons learned. Experience governs sequence, not lessons learnt. |
| | | 10.2 Benchmarking. | Yes | As the benchmark is considered as a trial to highlight problems in the construction process. |
| | | 10.3 Construction information databases. | Yes | Because data is already available. |
| 11 | Reducing the insufficient use of information technology can be achieved by: | 11.1 Implementation of an enhanced information management platform. | Yes | New platforms allow more advanced information sharing. Furthermore, it allows remote access to databases without physical presence near the servers. |

The interviewee highlighted that the impact of the discussed solutions will vary based on the level and the quality of implementation. Furthermore, the interviewee reckons that Enhanced technology and the can-do approach have the most important role in reducing rework among the proposed solutions. He believes that the absence of the can-do approach in any time should be highlighted. This is since such absence could be simply due to poor attitude towards the duty rather than problematic information or tasks.

### 7.3.3 Feedback from construction professional with management background:

Below describes the interview conducted with a management related professional with contracting background. The interview was conducted on the 26th of May 2018.

*Table 7: Feedback from a management oriented construction professional with contracting background*

| No. | Challenge | Solution | Yes/ No | Comments |
|---|---|---|---|---|
| 1 | Reducing unanticipated design load and design changes due to errors and missing information can be achieved by | 1.1 Quality assignment of tasks within the last planner. | Yes | Because it allows operation teams to plan and study possibility of execution within given conditions. |
| | | 1.2 Adopting a "can-do" approach within the last planner. | Yes | Because it allows operation teams to analyse the proposed details and construction methodology before committing to a delivery date. |
| | | 1.3 Incorporating design deliverables schedule with the last planner. | Yes | This is since it specifies sources of information and avoids multiple answers for the same question from different parties. |
| | | 1.4 Contract documents review and validation. | Yes | As it helps identify errors and missing information early on before becoming critical. |
| | | 1.5 The implementation of an enhanced information management platform. | Yes | As it provides enhanced accessibility to information. |
| | | 1.6 Benchmarking. | Yes | As the benchmark will allow the creation of a physical sample of the design from which lessons can be learned and mistakes can be avoided. |
| | | 1.7 Construction information databases. | Yes | Information can be accessible rather than being created if it was missing. |
| 2 | Reducing limited access to latest information by the construction teams can be achieved by: | 2.1 Quality assignment of tasks within the last planner. | Yes | As quality assignment requires providing relevant information or at least an introduction to the information source. |
| | | 2.2 Implementation of an enhanced information management platform. | Yes | Because accessibility to information is enhanced thanks to the enhanced information management platform. |
| 3 | Reducing rectification of construction non-conformance and | 3.1 Quality assignment of tasks within the last planner. | Yes | Because relevant information is included in the quality assignment. |

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| | errors can be achieved by: | 3.2 The implementation of an automated area access record. | Yes | Because correct work sequence is enforced by the AAR which will prevent out of sequence work and inaccurate execution (inspection by QA/QC). Such framework will reduce non-conformances. |
| | | 3.3 Benchmarking. | Yes | As the full scope of a small area is carried highlighting issues with sequence. |
| 4 | Reducing time boxing can be achieved by: | 4.1 Adopting a “can-do” approach within the last planner. | Yes | As can-do approach includes planning which help shield production of information and ultimately execution. |
| | | 4.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | As it specifies sources of information and avoids multiple answers with short period which improves productivity. |
| | | 4.3 Construction information databases. | Yes | As the data base can help aid in the anticipation of the duration a task is required by experience. |
| 5 | Reducing misalignment between information readiness and construction activities can be achieved by: | 5.1 Adopting a “can-do” approach within the last planner. | Yes | Because it allows planning for long lead items for example. |
| | | 5.2 Adopting design deliverables schedule incorporated with the last planner. | No | Design is not relevant to construction as this will aid the design, not the construction. |
| | | 5.3 Construction information databases. | Yes | As the data base can help aid in the anticipation of the duration a task is required by experience. As well as inform on sequence of works. |
| 6 | Reducing poor quality of information can be achieved by: | 6.1 Adopting a “can-do” approach within the last planner. | Yes | As planning within a can-do approach increase the quality of information as operation teams are more aware of a task’s requirements. |
| | | 6.2 Adopting checklists into the last planner system. | Yes | It can help if it designed properly as it highlights the requirements a task needs to satisfy. |
| | | 6.3 Adopting design deliverables schedule incorporated with the last planner. | Yes, | As it specifies sources of information and avoids multiple answers from different parties. |
| | | 6.4 Implementation of an enhanced information management platform. | Yes | As it will aid in the identification of changes between different revisions for example. |

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| | | 6.5 Benchmarking. | Yes | It will identify problems in the existing design (if any) and help resolve them. |
| | | 6.6 Incorporating information release schedule with the last planner system. | No | It's not relevant. |
| 7 | Reducing missing and inaccurate information in the design documents (contract docs) can be achieved by: | 7.1 Adopting a "can-do" approach within the last planner. | Yes | As allowing sufficient time to prepare information can help reduce errors in the created information by the contractor. Because they will have sufficient time to clear any incorrect or missing information in the contract documents. |
| | | 7.2 Adopting design deliverables schedule Incorporated with the last planner. | Yes | Because as it specifies sources of information and avoids multiple answers from different entities. It makes the process of identifying and tackling missing information simpler and easier. |
| | | 7.3 Implementation of an enhanced information management platform. | Yes | Enhanced accessibility to information enhances the chance to pick up missing or incorrect information to sort them out. |
| | | 7.4 The implementation of an automated area access record. | No | It's not relevant. |
| | | 7.5 Benchmarking. | Yes | As the full scope of a small area is carried out highlighting any errors or missing information in the design documents. |
| 8 | Reducing lack of discipline (working out of sequence) can be achieved by: | 8.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | Because the DDS is controlling the sequence of different activities. |
| | | 8.2 The implementation of an automated area access record. | Yes | As the AAR will govern accessibility to working zones. |
| | | 8.3 Benchmarking. | Yes | As the full scope of a small area is carried out highlighting issues with sequence. |
| 9 | Reducing lack of awareness of the scope of work of each entity within contractors and | 9.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | By having a DDS during the design stage, it will help identify scope gaps. |

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| | subcontractors can be achieved by: | 9.2 The implementation of an automated area access record. | No | It's not relevant. |
| | | 9.3 Benchmarking. | Yes | As the full scope of a small area is carried highlighting any un-awarded or unidentified scope. |
| 10 | Reducing failure to learn from previous mistakes can be achieved by: | 10.1 The implementation of an automated area access record. | No | Not applicable. |
| | | 10.2 Benchmarking. | Yes | As the full scope of a small area is carried highlighting issues with sequence, design, execution, etc. |
| | | 10.3 Construction information databases. | Yes | It shares previous experiences with any problems. |
| 11 | Reducing the insufficient use of information technology can be achieved by: | 11.1 Implementation of an enhanced information management platform. | No | As the technology used is dependent on the users. |

The interviewee highlighted that the construction database seems the most promising from the different proposed solutions above. This is since the data base can provide various type of information which help resolve a problem or at least identify approximate required duration for the conclusion of an activity. Moreover, the interviewee emphasized on the importance of training and education for site staff for such ideas to be properly implemented and for positive results to be obtained.

### 7.3.4 Feedback from construction professional with Quality control (QA-QC) background:

Below describes the interview conducted with a quality control (QA-QC) related professional with contracting background. The interview was conducted on the 13th of May 2018.

*Table 8: Feedback from a QA/QC oriented construction professional with contracting background*

| No. | Challenge | Solution | Yes/ No | Comments |
|---|---|---|---|---|
| 1 | Reducing unanticipated design load and design changes due to errors and missing information can be achieved by | 1.1 Quality assignment of tasks within the last planner. | Yes | It will ensure all requirements to carry on an activity is present and ready to be utilized so as reduce or remove any negative impact on the activity's progress. |
| | | 1.2 Adopting a "can-do" approach within the last planner. | No | Because unanticipated works can happen. |
| | | 1.3 Incorporating design deliverables schedule with the last planner. | Yes | As it controls the coordination processes by governing both information flow and information release. |
| | | 1.4 Contract documents review and validation. | Yes | Because knowing problems ahead will help reduce delays and surprises in the future. |
| | | 1.5 The implementation of an enhanced information management platform. | Yes | As it enhances the awareness of the contract documents due to enhanced access. |
| | | 1.6 Benchmarking. | Yes | Missing information in the mock up will identify gaps that may require design intervention. Such processes may cause design unanticipated load if they remain unknown. |
| | | 1.7 Construction information databases. | Yes | Since constraints can be tackled by referring to previous experiences. |
| 2 | Reducing limited access to latest information by the construction teams can be achieved by: | 2.1 Quality assignment of tasks within the last planner. | Yes | Because quality assignment is characterized with clarity and being up to date. Therefore, access to latest relevant information is achieved with quality assignment. |
| | | 2.2 Implementation of an enhanced information management platform. | Yes | Ease of access provides more chance of picking up latest information by executers and inspectors. |
| 3 | Reducing rectification of construction non-conformance and errors can be achieved by: | 3.1 Quality assignment of tasks within the last planner. | Yes | Because construction teams have access to all requirements for an activity. |
| | | 3.2 The implementation of an automated area access record. | Yes | It provides restriction to follow work sequence. |
| | | 3.3 Benchmarking. | Yes | The purpose of a benchmark is to identify the areas of weakness in |

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| | | | | the design or construction and address them during delivery. |
| 4 | Reducing time boxing can be achieved by: | 4.1 Adopting a "can-do" approach within the last planner. | Yes | Allows the executing team to gauge the required time to conclude a task and proceed accordingly. |
| | | 4.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | As it will provide clearer understanding of the task's requirements and prerequisites. |
| | | 4.3 Construction information databases. | Yes | Because ready-made information can be accessible. |
| 5 | Reducing misalignment between information readiness and construction activities can be achieved by: | 5.1 Adopting a "can-do" approach within the last planner. | Yes | Designers and detailers will only commit to reasonably achievable targets which will increase the chance of delivery. |
| | | 5.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | As it will provide clearer understanding of the task's requirements and prerequisites which will aid in ensuring a timely release of information. |
| | | 5.3 Construction information databases. | Yes | Because ready-made information can be accessible which improves action time. |
| 6 | Reducing poor quality of information can be achieved by: | 6.1 Adopting a "can-do" approach within the last planner. | Yes | Allows the executing team to gauge the required time to conclude a task and proceed accordingly more time dedicated to the task can enhance the quality. |
| | | 6.2 Adopting checklists into the last planner system. | Yes | Checklists act as a monitoring tool. |
| | | 6.3 Adopting design deliverables schedule incorporated with the last planner. | Yes, | As it will provide clearer understanding of the task's requirements and prerequisites. |
| | | 6.4 Implementation of an enhanced information management platform. | No | Not relevant |
| | | 6.5 Benchmarking. | Yes | Because undesired outcomes can be identified in the mock up. |
| | | 6.6 Incorporating information release schedule with the last planner system. | Yes | Yes, as it provides a clear picture on a task's characteristics such as start and end date. |

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| 7 | Reducing missing and inaccurate information in the design documents (contract docs) can be achieved by: | 7.1 Adopting a “can-do” approach within the last planner. | Yes | As allowing sufficient time for a task can help detect and resolve discrepancies within it. |
| | | 7.2 Adopting design deliverables schedule Incorporated with the last planner. | No | Not relevant. |
| | | 7.3 Implementation of an enhanced information management platform. | No | Not relevant |
| | | 7.4 The implementation of an automated area access record. | Yes | Because it can identify missing scope, which possibly resulted from missing or inaccurate information in the contract documents. |
| | | 7.5 Benchmarking. | Yes | A mock up requires the execution of all relevant activities to provide a finished product. |
| 8 | Reducing lack of discipline (working out of sequence) can be achieved by: | 8.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | The schedule will provide the sequence required which when not followed, the information provided is not accurate. |
| | | 8.2 The implementation of an automated area access record. | Yes | It provides restriction to follow work sequence. |
| | | 8.3 Benchmarking. | No | As mock ups are generally intended for final products for quality reference. |
| 9 | Reducing lack of awareness of the scope of work of each entity within contractors and subcontractors can be achieved by: | 9.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | Because absence of feedback from a party is not in line with the design deliverables schedule will render information incomplete. So, it highlights the missing scope to the concerned people. |
| | | 9.2 The implementation of an automated area access record. | No | If the activity was not picked up in the design carried out by a subcontractor, it is very unlikely to be picked up by the AAR. |
| | | 9.3 Benchmarking. | Yes | A mock up requires the execution of all relevant activities to provide a finished product. |
| 10 | Reducing failure to learn from previous mistakes can be achieved by: | 10.1 The implementation of an automated area access record. | Yes | Because AAR is based on lessons learned. |
| | | 10.2 Benchmarking. | Yes | Because the bench mark is a lesson learned in itself which can be utilized for the rest of the project. |
| | | 10.3 Construction information databases. | Yes | Because we are referring to previous experience essentially. |

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| 11 | Reducing the insufficient use of information technology can be achieved by: | 11.1 Implementation of an enhanced information management platform. | Yes | Because the enhanced information management platform will allow integration with latest information technology. |

The interviewee emphasized on the importance of construction education to all staff and the fact that each executing party should be fully aware of the requirements of the task they are about to undertake. Such knowledge can significantly reduce the rework processes as a result. Whereas spontaneous execution without sufficient knowledge can create rework and abortive efforts. Furthermore, the interviewee also emphasized on the importance of reporting. In his opinion, lack of rework incident reporting is hindering the action to element such processes. This is because there is not enough supporting evidence during project progress to build the business case for implementing counter processes to eliminate rework. Moreover, such reporting is not even done when the project is finished to be taken over as lessons learnt in the next project. Therefore, it only goes down to what individual have learnt on their own and whether they were willing to do something about it in the next project.

### 7.3.5 Feedback from construction professional with planning background:

Below describes the interview conducted with a planning related professional with contracting background. The interview was conducted on the 19th of May 2018.

*Table 9: Feedback from a planning oriented construction professional with contracting background*

| No. | Challenge | Solution | Yes /No | Comments |
|---|---|---|---|---|
| 1 | Reducing unanticipated design load and design changes due to errors and missing information can be achieved by | 1.1 Quality assignment of tasks within the last planner. | Yes | The assigning person will control when a construction activity will start so with that he will have a better chance avoid out of sequence work. Therefore, he will reduce the chances of errors that will cause unanticipated design load. |

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| | | 1.2 Adopting a "can-do" approach within the last planner. | No | Because such approach should already be in place when the base construction program is formalized. The buy-in is obtained then, not for each individual activity. |
| | | 1.3 Incorporating design deliverables schedule with the last planner. | Yes | It provides a clear idea of what needs to be done before a design activity can start. |
| | | 1.4 Contract documents review and validation. | Yes | It helps highlight any gaps in the design provided by the client/consultant. These gaps can be addressed before the actual design activity start reducing its impact on the overall design cycle of a project. |
| | | 1.5 The implementation of an enhanced information management platform. | Yes | It provides ease of access to progress status of design. Which will help identify if certain design activities are not being concluded in time and are affecting the start date of the following activities. Allowing decision makers to take corrective action and preventing the following activities from starting on inaccurate information. |
| | | 1.6 Benchmarking. | Yes | It will confirm the design development is aligned with the design intent and it will confirm the followed sequence for construction is correct. |
| | | 1.7 Construction information databases. | Yes | Detailing is obtained (and most importantly implemented and accepted) from previous projects rather than recreated. |
| 2 | Reducing limited access to latest information by the construction teams can be achieved by: | 2.1 Quality assignment of tasks within the last planner. | Yes | Quality assignment ensures latest information is available and accessible. |
| | | 2.2 Implementation of an enhanced information management platform. | No | If the information is not ready from its source or is not communicated, then the level of sophistication of the information management technology won't matter. |
| 3 | Reducing rectification of construction non-conformance and errors can be achieved by: | 3.1 Quality assignment of tasks within the last planner. | Yes | Quality assignment ensures that previous relevant activities are concluded before an activity can start. |
| | | 3.2 The implementation of an automated area access record. | Yes | It will make tracking activities and sequence on site more efficient which should reduce construction errors. |
| | | 3.3 Benchmarking. | Yes | It will confirm that the execution methodology and the sequence followed is correct and will highlight any flaws in the same. |

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| 4 | Reducing time boxing can be achieved by: | 4.1 Adopting a "can-do" approach within the last planner. | No | Because such approach should already be in place when the base construction program is formalized. The buy-in is obtained then, not for each individual activity. |
| | | 4.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | As it will identify what an activity needs to commence. Therefore, it omits the time an activity is idle waiting for input from previous activity. Allowing the activity to maintain its planned duration. |
| | | 4.3 Construction information databases. | Yes | It will accelerate the detailing processes as the design team can obtain details from previous projects or experiences. |
| 5 | Reducing misalignment between information readiness and construction activities can be achieved by: | 5.1 Adopting a "can-do" approach within the last planner. | No | Because such approach should already be in place when the base construction program is formalized. The buy-in is obtained then, not for each individual activity. |
| | | 5.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | As it will identify what an activity needs to commence. Therefore, it omits the time an activity is idle waiting for input from previous activity. Alerting all relevant team members of the delay. |
| | | 5.3 Construction information databases. | Yes | It will make detailing processes faster as the design team can obtain details from previous projects or experiences. |
| 6 | Reducing poor quality of information can be achieved by: | 6.1 Adopting a "can-do" approach within the last planner. | No | Because such approach should already be in place when the base construction program is formalized. The buy-in is obtained then, not for each individual activity. |
| | | 6.2 Adopting checklists into the last planner system. | Yes | It validates the accuracy of the communicated information. |
| | | 6.3 Adopting design deliverables schedule incorporated with the last planner. | Yes , | As it will identify what an activity needs to commence. Therefore, it omits the time an activity is idle waiting for input from previous activity. |
| | | 6.4 Implementation of an enhanced information management platform. | No | Quality of information is dependent on the source and the measures taken to produce quality information. This is rarely impacted by the medium it is accessed from. |
| | | 6.5 Benchmarking. | Yes | It will confirm the design development is aligned with the design intent. |
| | | 6.6 Incorporating information release schedule with the last planner system. | Yes | IRS usually highlight the duration required to release information and how that is linked to procurement and installation. |

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| | | | | Therefore, it incorporates the time required by the designers to provide usable information which reduces inaccuracy. |
| 7 | Reducing missing and inaccurate information in the design documents (contract docs) can be achieved by: | 7.1 Adopting a “can-do” approach within the last planner. | No | Not relevant. Designers and detailers can commit to deadline only to find out that they are missing certain information that was not there in the IFC documents. This will now delay them from their commitment. |
| | | 7.2 Adopting design deliverables schedule Incorporated with the last planner. | No | Not relevant. |
| | | 7.3 Implementation of an enhanced information management platform. | No | Information platform doesn’t impact the quality of information that is being circulated on that platform. |
| | | 7.4 The implementation of an automated area access record. | No | Not relevant. |
| | | 7.5 Benchmarking. | Yes | The full benchmark will require the full information concerning it to be present. Otherwise, the benchmark will not be concluded. |
| 8 | Reducing lack of discipline (working out of sequence) can be achieved by: | 8.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | The DDS will provide the sequence that design needs to be adhered to. |
| | | 8.2 The implementation of an automated area access record. | Yes | The AAR will provide the sequence that construction needs to be adhered to. |
| | | 8.3 Benchmarking. | Yes | Benchmark will validate the proposed sequence for the rest of the project. |
| 9 | Reducing lack of awareness of the scope of work of each entity within contractors and subcontractors can be achieved by: | 9.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | This will inform all relevant parties of their design requirements to plan accordingly. |
| | | 9.2 The implementation of an automated area access record. | No | If the activity was not picked up in the design carried out by a subcontractor, it is very unlikely to be picked up by the AAR. |
| | | 9.3 Benchmarking. | Yes | Any missing item in the finished mock up illustrates a scope not awarded or not designed. |
| 10 | Reducing failure to learn from previous mistakes can be achieved by: | 10.1 The implementation of an automated area access record. | Yes | AAR is established based on experience. Automating the ARR makes the construction sequence easier to follow. |

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| | | 10.2 Benchmarking. | Yes | The benchmark is literally an experiment to test how design, planning and execution work together. |
| | | 10.3 Construction information databases. | Yes | The database provides easier access to previous experiences which helps adopting them in construction. |
| 11 | Reducing the insufficient use of information technology can be achieved by: | 11.1 Implementation of an enhanced information management platform. | Yes | Because information management platform can be the reason why a certain information technology is not used. |

The interviewee emphasized on the importance of communication between the planners and other construction related departments. This will help highlight any program slippage allowing concerned management staff to take action. Furthermore, he endorsed the last planner program in its potential benefits but the interviewee cited that he didn't utilize this system in his previous projects.

## 7.4 Interviews summary:

The solutions proposed were reviewed by the interviewees as discussed in the previous sections of this chapter. Comments consistency varied between different interviewees which indicates that perspectives on the viability of a solution are different between an interview and other (summary of the comments is illustrated in Table 10). This can be caused by difference in background, experience or personal opinion.

*Table 10: Summary of interview responses*

| No. | Challenges as identified in Table 3 | Solutions as identified in Table 4 | Design | Operations | Management | QA/QC | Planning | Agreement Percentage |
|---|---|---|---|---|---|---|---|---|
| 1 | Reducing unanticipated design load and design changes due to errors and missing information can be achieved by | 1.1 Quality assignment of tasks within the last planner. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 1.2 Adopting a "can-do" approach within the last planner. | Yes | Yes | Yes | No | No | 60% |
| | | 1.3 Incorporating design deliverables schedule with the last planner. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | | Yes | Yes | Yes | Yes | Yes | 100% |

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| | | 1.4 Contract documents review and validation. | | | | | | |
| | | 1.5 The implementation of an enhanced information management platform. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 1.6 Benchmarking. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 1.7 Construction information databases. | Yes | Yes | Yes | Yes | Yes | 100% |
| 2 | Reducing limited access to latest information by the construction teams can be achieved by: | 2.1 Quality assignment of tasks within the last planner. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 2.2 Implementation of an enhanced information management platform. | Yes | Yes | Yes | Yes | No | 80% |
| 3 | Reducing rectification of construction non-conformance and errors can be achieved by: | 3.1 Quality assignment of tasks within the last planner. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 3.2 The implementation of an automated area access record. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 3.3 Benchmarking. | Yes | Yes | Yes | Yes | Yes | 100% |
| 4 | Reducing time boxing can be achieved by: | 4.1 Adopting a “can-do” approach within the last planner. | Yes | Yes | Yes | Yes | No | 80% |
| | | 4.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 4.3 Construction information databases. | No | No | Yes | Yes | Yes | 60% |
| 5 | Reducing misalignment between information readiness and construction activities can be achieved by: | 5.1 Adopting a “can-do” approach within the last planner. | Yes | Yes | Yes | Yes | No | 80% |
| | | 5.2 Adopting design deliverables schedule incorporated with the last planner. | Yes | Yes | No | Yes | Yes | 80% |
| | | 5.3 Construction information databases. | Yes | Yes | Yes | Yes | Yes | 100% |

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| 6 | Reducing poor quality of information can be achieved by: | 6.1 Adopting a “can-do” approach within the last planner. | Yes | Yes | Yes | Yes | No | 80% |
| | | 6.2 Adopting checklists into the last planner system. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 6.3 Adopting design deliverables schedule incorporated with the last planner. | Yes, | Yes, | Yes, | Yes, | Yes, | 100% |
| | | 6.4 Implementation of an enhanced information management platform. | Yes | Yes | Yes | No | No | 60% |
| | | 6.5 Benchmarking. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 6.6 Incorporating information release schedule with the last planner system. | Yes | Yes | No | Yes | Yes | 80% |
| 7 | Reducing missing and inaccurate information in the design documents (contract docs) can be achieved by: | 7.1 Adopting a “can-do” approach within the last planner. | Yes | Yes | Yes | Yes | No | 80% |
| | | 7.2 Adopting design deliverables schedule Incorporated with the last planner. | No | No | Yes | No | No | 20% |
| | | 7.3 Implementation of an enhanced information management platform. | Yes | Yes | Yes | No | No | 60% |
| | | 7.4 The implementation of an automated area access record. | No | No | No | Yes | No | 20% |
| | | 7.5 Benchmarking. | Yes | Yes | Yes | Yes | Yes | 100% |
| 8 | Reducing lack of discipline (working out of sequence) can be achieved by: | 8.1 Adopting design deliverables schedule incorporated with the last planner. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 8.2 The implementation of an automated area access record. | Yes | Yes | Yes | Yes | Yes | 100% |

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|---|---|---|---|---|---|---|---|---|
| | | 8.3 Benchmarking. | Yes | Yes | Yes | No | Yes | 80% |
| 9 | Reducing lack of awareness of the scope of work of each entity within contractors and subcontractors can be achieved by: | 9.1 Adopting design deliverables schedule incorporated with the last planner. | No | No | Yes | Yes | Yes | 60% |
| | | 9.2 The implementation of an automated area access record. | Yes | Yes | No | No | No | 40% |
| | | 9.3 Benchmarking. | Yes | Yes | Yes | Yes | Yes | 100% |
| 10 | Reducing failure to learn from previous mistakes can be achieved by: | 10.1 The implementation of an automated area access record. | No | No | No | Yes | Yes | 40% |
| | | 10.2 Benchmarking. | Yes | Yes | Yes | Yes | Yes | 100% |
| | | 10.3 Construction information databases. | Yes | Yes | Yes | Yes | Yes | 100% |
| 11 | Reducing the insufficient use of information technology can be achieved by: | 11.1 Implementation of an enhanced information management platform. | Yes | Yes | No | Yes | Yes | 80% |

# Chapter 8: Conclusion

## 8.1 Conclusion:

This chapter will illustrate the conclusion of this research. This conclusion was synthesized utilizing a through literature review and employing different research methodologies.

The significance of the study lies with the fact that the construction industry is a hasty process often accompanied with missing information and mis-coordination. Therefore, it helps set the ground work for the solutions that can be implemented to eliminate rework and therefore eliminate waste. Such solutions can be adopted by construction professionals and contractors reflecting both materialistic and environmental benefits on the construction industry. These different solutions were proposed and validated to suit the condition of the construction sector in UAE.

Design, execution, planning and management related solutions were proposed providing a framework for construction in UAE that is adoptable by contractors in post contract award stage of a project. This framework is characterized as being both static (a system that is only implemented in a single project and has nothing to do with other projects) and dynamic (a system that continues to grow in impact by experience). The objective of this framework is to reduce as much as possible the rework activities in construction.

The proposed solutions include quality assignment of tasks as part of the Last Planner (LP) system, Establishing the design deliverables schedule and incorporating it into the Last Planner system, the implementation of task conclusion checklists within the last planner, the review of the contract documents by experience technical staff, the implementation of an enhanced information management platform, the utilization of the benchmarking system, the creation and maintenance of a construction information data base, the implementation of an automated area access record. Such solutions are proved to be successful in reducing rework in the construction industry in UAE which can be considered as sustainable strategies to reduce construction waste.

The most important strategy which was part of a group of the proposed solutions is the Last Planner system. The significance of this system lies in the fact that it shields production by sorting out and organizing information. Which reduce the chances of an activity being executed incorrectly. Furthermore, it allows qualities of construction professionals such as accountability and commitment to be utilized in a structured manner to achieve the end product.

The research also identified that rework is often created due to lack of experience or knowledge. Therefore, in order to reduce rework and ultimately reduce waste of the construction industry, the research proposed to adopt lessons learned from previous projects or experiences. This knowledge can be harnessed in two main stratigies, the first is to create a benchmark of what needs to be built which can provide insights on the shortcomings of the utilized activities to create this benchmark. Such insights can then be utilized to develop an enhanced set of activities which can deliver the product more efficiently. The second strategy is to adopt what is known as a construction data base. Such data base will include knowledge and experiences created by individuals who were part of construction projects previously. The documentation of the methods, tools, sequences, designs and outcomes can be later on accessed to obtain a similar result to what was done previously or at least avoid a problem.

Furthermore, the implementation of a record of construction activities each zone in a construction projects experience has become significantly more critical. This is since the amount of entities that need to work in a certain zone is increasing in relation to how sophisticated our buildings become. Therefore, controlling sequence and managing access through an automated AAR system can help reduce rework due to out of sequences activities dramatically.

Moreover, adopting some form of responsibility matrix among different technical teams of contractors and subcontractors can significantly improve the information quality being shared to site. This matrix can be developed as Design Deliverables Schedule which will clearly communicate the design activities that needs to take place and which activities needs to precede them. Allowing design activities to be carried out in a structured manner, based on latest information and within predicted time frame.

All the solutions proposed in this research form part of the construction knowledge management processes of which this research had aimed to illustrate its role in reducing rework in the construction sector. Contractors needs to acknowledge the impact rework have not only to the environment because of waste but to their efficiency of execution.

## 8.2 Limitation:

The solutions proposed in this research were a reflection to the current condition of the construction sector in UAE and doesn't reflect what is being utilized globally as solutions to tackle the epidemic of rework in the construction sector. This directed the research to propose solutions that are compatible with the current conditions of the construction sector in UAE rather than what is currently being utilized in developed parts of the world. the application of each of the solutions could be implemented with BIM as its platform which would significantly increase its performance. However, due to the lack of adaptation of BIM as a construction management tool rather than an enhanced drafting software has hindered the adaptation of such approach in this research.

## 8.3 Recommendation for future research:

Rework in construction have addressed widely in the literature yet it seems that it continues to provide a general perspective about its causes and preventive remedies. Below are potential future research scopes that can further clarify the concepts of rework reduction through knowledge management solutions in UAE:

- The implementation of the Last Planner system should be evaluated and challenged in construction project.

- The dynamics of the creation of a construction data base and how such idea can propagates into a common construction data source that will become part of the contract documents of a project.
- Evaluating the feasibility of strategies to review contract documents before project award to minimize impact of missing or inaccurate information on construction.
- Evaluate the amount of waste reduced due the implementation of the proposed solutions by reporting rework event, their impact and cause.

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# Appendices

# Appendix A: Survey questionnaire structure:

1. Which part of the construction industry do you belong to:

- ○ Contractor – Engineering & Design
- ○ Contractor - Operations
- ○ Consultant – Engineering & Design
- ○ Consultant – Site
- ○ Developer

2. What would you estimate the percentage of rework tasks/activities within your daily routine in your current role:

- ○ Less than 10%
- ○ Less than 30%
- ○ Less than 50%
- ○ Less than 80%

### 3. Rework is defined by The Construction Industry Development Agency as “doing something at least one extra time due to non-conformance to requirements”. In your opinion, how would you rank the following factors in how vital their role is in the creation of rework:

| | 1 (Most Important) | 2 | 3 | 4 | 5 (Less Important) |
|---|---|---|---|---|---|
| Design related factors (complexity, information availability, coordination, clarity, etc.). | ○ | ○ | ○ | ○ | ○ |
| Contractor related factors (Workmanship, Construction planning, resources availability, Quality control, etc.). | ○ | ○ | ○ | ○ | ○ |
| Client related factors (Changes in design, Design briefing, Budgeting, etc.). | ○ | ○ | ○ | ○ | ○ |
| Project related factors (Site constraints, Accessibility, Location, etc.). | ○ | ○ | ○ | ○ | ○ |
| External Factors (Municipal Building Codes, Economy, Security, etc.). | ○ | ○ | ○ | ○ | ○ |

### 4. How significant can the below causes help create rework in your opinion:

| | Not important | Moderate importance | Very important |
|---|---|---|---|
| Poor communication between the client and the consultant during the design briefing. | ○ | ○ | ○ |
| Poor communication between the lead consultant and the sub-consultants during the design stage. | ○ | ○ | ○ |
| Lack of relevant or sufficient expertise within the assigned design/technical teams. | ○ | ○ | ○ |
| Design is set to be executed with certain construction systems and techniques that are outdated. | ○ | ○ | ○ |

| | | | |
|---|---|---|---|
| Unanticipated design load and design changes due to errors, missing information and unforeseen site conditions. | ○ | ○ | ○ |
| Competitive bidding by the consultants, which leads to Time Boxing; which is basically setting a fixed duration for each design task regardless of its status being completed or not. | ○ | ○ | ○ |
| Misalignment between information readiness and the commencement of construction activities. | ○ | ○ | ○ |
| Suppliers or subcontractor not on-board with the construction and planning progress due to unconcluded commercial issues. | ○ | ○ | ○ |
| Insufficient use of information technology | ○ | ○ | ○ |
| Insufficient skill and workmanship levels | ○ | ○ | ○ |
| Changes of design induced by client | ○ | ○ | ○ |
| Financial problems faced by the client | ○ | ○ | ○ |
| Client's indecisiveness | ○ | ○ | ○ |
| Client's insistent nature | ○ | ○ | ○ |
| Poor site investigations prior to project design | ○ | ○ | ○ |
| Poor managerial qualities in construction | ○ | ○ | ○ |

| | | | |
|---|---|---|---|
| Limited access to latest information by the construction teams | ○ | ○ | ○ |
| Lack of discipline between different parties involved in the construction process | ○ | ○ | ○ |
| Lack of construction resources | ○ | ○ | ○ |
| Lack or poor construction planning | ○ | ○ | ○ |
| Failure to learn from previous mistakes | ○ | ○ | ○ |

Other (please specify)

### 5. Within the Contractor's scope, how effective would the following steps help in reducing rework in your opinion:

| | Not important | Moderate importance | Very important |
|---|---|---|---|
| Early appointment of the technical team within the contractor prior to construction commencement to go through the contract documents. | ○ | ○ | ○ |
| Imposing time and cost claims on the client for providing insufficient or uncoordinated contract documents. | ○ | ○ | ○ |
| Imposing time and cost claims on the client in the event of change as part of the construction contract. | ○ | ○ | ○ |

| | | | |
|---|---|---|---|
| Early engagement with sub-contractors/suppliers to improve their readiness to participate in the project technically once awarded. | ○ | ○ | ○ |
| Formation and maintenance of Responsibility Matrix where each team provides their deliverables (dated) and their requirements (dated) from other teams. | ○ | ○ | ○ |
| Employing a system of dependency between information where a drawing will be indicated as Outdated if one or more of its reference drawings gets updated. | ○ | ○ | ○ |
| Implementing an Area Access Record system to monitor work sequence and minimize out of sequence work on site. | ○ | ○ | ○ |
| Implementation of constructability reviews per area to ensure alignment between the design intent of the technical team and what is being built on site avoiding rework due to misinterpretation of drawings. | ○ | ○ | ○ |
| Establishing a single communication platform which is accessible to all parties. | ○ | ○ | ○ |

Other (please specify)

6. What is the current level of BIM implementation in your company in your opinion ?

- ◯ Not implemented
- ◯ Semi implemented
- ◯ Fully implemented

7. What is the driver behind the current level of BIM implementation in your firm in your opinion?

8. Does the interface between entities with different level of BIM implementation help create rework in your opinion ?

- ◯ Yes
- ◯ No

9. Please provide any additional information or issues which can help reduce rework in the construction industry.

- ◯ No, thanks!
- ◯ Yes ( please type here)