Construction Material Tracking and Reduction of Material Waste on Site using a Web-Based Application - "ReCon Material"

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As Construction is highly dependent on natural resources and energy. If the construction materials are not used effectively, the amount of waste left in construction is proportionally large. To reduce the waste of construction materials, it is necessary to first understand why materials are wasted. An online database application is needed to effectively record which construction materials are used by whom and for what purpose. However, there is an economic burden for a small builder to have a database specialist who can develop such an application using a relational database. Recently, many tools have been released that make it easy for anyone to develop an online database application without the expertise of a database. These tools provide a great opportunity for construction companies to create their own database applications. This paper presents how we created a database application empirically that can track material usages, to demonstrate if these tools could help industry professionals develop their own database application. This paper also presents the lessons we learned while working on the experimental development.

Keywords: Knack, Construction, Material Waste, Tracking, Waste Reduction.

Introduction

Traditionally the construction industry is environmentally unfriendly. Environmental impacts due to construction and construction-related activity have always been a major concern. One of such impacts is caused by material waste generated during the construction. The construction industry has been found to be a major generator of waste. Craven *et al.* (1994) reported that construction activity is likely to generate ≈ 20-30% of all waste deposited in Australian landfills. According to Ferguson *et al.* (1995), more than 50% of the waste deposited in a typical landfill in the UK could be construction waste. Lanting (1993) found that construction waste constitutes 26% of the total amount of waste produced in the Netherlands. Rogoff & Williams (1994) reported that 29% of the solid waste stream in the USA consisted of construction waste. Research studies have also reported that construction waste constitutes 19% of the total waste deposited in landfills in Germany (Brooks *et al.* 1994) and 13-15% of the total waste deposited in landfills in Helsinki, Finland (Heino 1994).

To mitigate the waste, the construction manager must utilize management options as reuse, recycle and reduce (Fadiya, Georgakis & Chinyio, 2014). As the awareness of global warming and need to reduce waste increased among people, economic, political and social pressures to adopt sustainable work practices have led to renewed emphasis on developing effective waste minimization measures for major construction projects. The most effective measures were deemed to be those that fostered "Waste Minimisation Partnerships" throughout the supply chain (Dainty & Brooke, 2004). The paper presents two cases and results from semi-structured interviews which shed light on some of the major issues. Interview conducted show that client preference and existing law enforcement could help in implementing waste minimization effectively. Sites practices and storage are major causes of construction waste (Arif, Bendi & Toma-Sabbagh, 2012).

Material waste is recognized as a major dilemma in the construction industry and has important implications. The construction industry has been reported to be generating immense levels of material waste. Many researchers have been talking and researching about this from a long time. After doing the literature review, we found that more focus should be on the start of the construction process that is designing. A right design can make a lot of different with respect to construction waste. A work breakdown study should be conducted to identify the causes of waste and improve them to reduce and eventually eliminate it. If the design is right and sustainable with minimum wastage criteria, it plays a significant role.

Motivation

Construction stakeholders make major decisions in construction and related activities (Saez, Merino, Gonzalez, & Porras-Amores, 2013). The problem with this set-up is stakeholders are not fully equipped to make decisions as in most cases, people with little or no knowledge of construction and construction material make decisions which affects the project and the industry. Educating them with technical details is neither easy nor feasible with respect to time and the sheer complexity of construction projects. This is where the construction manager comes in and help the stakeholder make decisions. But what if the construction manager is short on knowledge & data regarding construction material and the causes of material waste.

The motivation behind the development of this web-based application and for this paper lies in equipping the managers of any construction project to make changes in the construction practices especially those pertaining to construction materials. In the age of technology and the internet of things, everything can be achieved using the same. As technology is leaning towards mobile devices as we progress swiftly in the future, it was only apt to develop a web-based to breach this information gap. Currently, there are a few web-based applications out there for managing inventory and handling construction materials. Applications such as Procore and Jonas Construction Software allows users to manage the material inventory, but these applications are limited to the management of material requirements and material stock for any given construction project.

In this paper, many online platforms were evaluated for developing an application, The Knack platform was finalized and used in the development as the platform is very intuitive. The knack platform is a cloud base platform which uses a database management system to develop web-based applications without requiring developer the knowledge of programming languages and coding. The platform is user-friendly and easy to implement. It uses a simple drag and drop interface, allowing the user to work with many objects and tables containing different data fields which can be interrelated to develop a flow of information without being repetitive.

Development

Construction industry faces many problems and issues with cannot be solved using traditional ways. As the technology is advancing rapidly, the idea of developing an application was formed to tackle one such issue. The issue which can be solved using an application. After weeks of brainstorming different issues and ideas, we decided to build ReCon Material. The application will be developed using databases, more precisely, Relational Databases.

A relational database is a set of formally described tables from which data can be accessed or reassembled in many ways without having to reorganize the database tables. The standard user and application programming interface (API) of a relational database is the Structured Query Language (SQL). In simple words, the relational database creates tables, enabling them to share data among themselves without duplicating the data. This is done using relations among the different table.

As Relational Database is a vast topic consisting of computer science, API and SQL, we decided to use Application Builder which uses Relational Database. Out of the many options available to develop a web-based application, Knack stood out the most. Therefore, ReCon Material was developed using Knack.
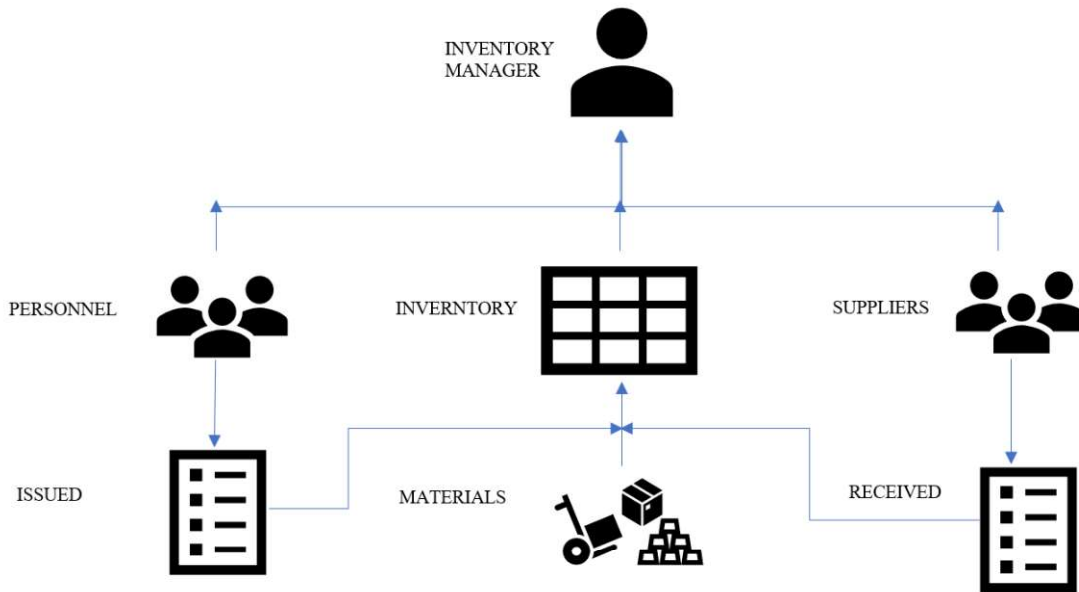

Image 1: How ReCon Material uses Relational Database

Knack is a web-based application builder that uses relational databases to relate information effectively and efficiently. It is best for people who don't have a background in computer science and knowledge of programming language and coding. Knack makes it easy to build applications that manage, share, and empower data.
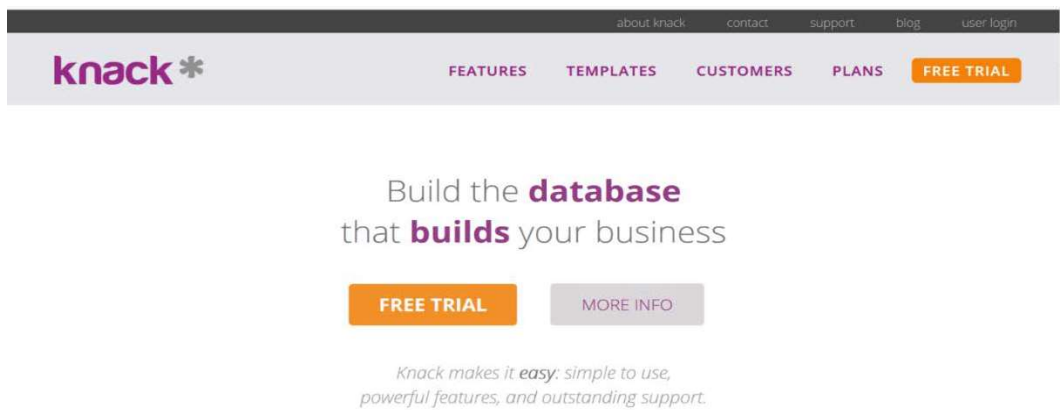

Image 2 - Knack Builder Homepage.

The development of "ReCon Material" app started with predesigns using traditional pen and paper. All the relevant parameters where defined and scope of the app was determined. Then the process was transferred to Knack. Knack provides an interface with the options of adding an object(tables) to add data to it which can form connections to share and use data among themselves which prevents data repetition.

A set of objects where defined with the parameters to hold different information relevant to that specific object. As for ReCon Material the objects that were created are Material to hold different parameters pertaining material information, Purchase to record purchases made from different suppliers and maintain the inventory, Issued to record material issued by personnel and the activity the material is issued for, Units to relate different material to their units, Personnel to record details of personnel working for the project, Suppliers to record information about different suppliers from whom the materials have been purchased. Connections were made among these objects to use and share information among themselves.
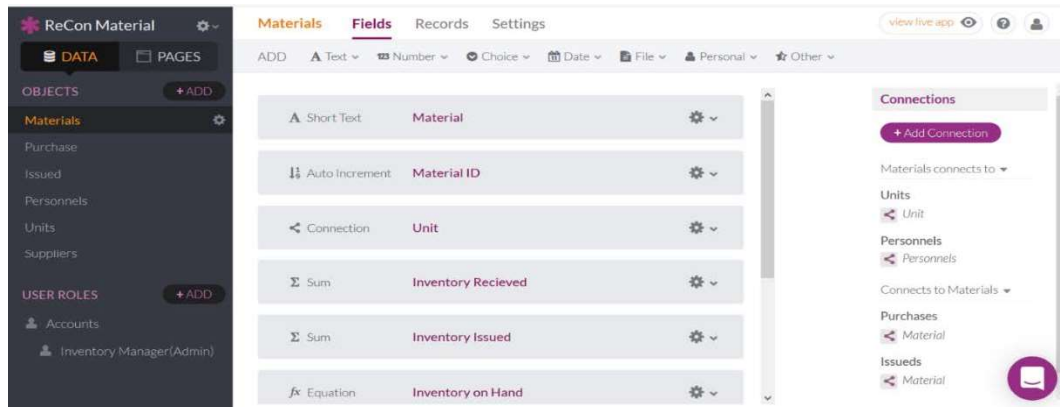

Image 3 - Objects developed in ReCon Material using Knack.

Different parameters for each object where well defined with individual characteristics to record, store, calculate and function using predefined information and information provided by the user. These parameters play a significant role to enhance the productivity of the object and serve as a basic cell block for the application. After creating all the objects and parameters and defining their functions, the user interface was the next step. The user interface is one of the most important things for any application as it determines whether the user understands the functionality of the application if the application is easy to understand and how long does it take for the user to implement the application in real life replacing the traditional ways they are used. In the building of the ReCon Material application, these factors were kept in mind.

Image 4 - The interface of ReCon Material Application.

Knack allows the user to define the outlook of their application using Pages. The developer can create different pages for the interface of the application. These pages can be created using the already

developed objects or blank depending on how the developer wants the application to function. For ReCon Material, all pages where created blank and objects were added to the pages later as a predesign for the application was thought. We made some changes to the design which we generated using pen and paper as was suitable for the application. The pages that were created are Current Inventory, Material Received, Material Issued, Personnel, and Suppliers. Each page served a different purpose as the name suggests. The most important of these pages was the Material Issued page. This page provided the personnel the form to issue the required material with a mandatory field 'Reason(For what Activity)'. As the name suggests this field asked the personnel issuing the material the activity or task they are issuing the material for. This gives the manager a detailed list of tasks for which the material was issued and if the material was reissued for the same task needing more quantity of material than estimated. Personnel is required to enter what lead to the requirement of extra material for the given activity than the estimated quantity.

Image 5 - Issued Page from ReCon Material Application.

Other Pages that were created are Current Inventory, Material Received, Personnel and Suppliers. Current Inventory page gives the manager information about the materials like how much material is available in the inventory, quantity of material purchased and issued and if any material needs reordering. It also allows the manager to add new material to the inventory. Material Received page to give information about what material has been purchased and the supplier it is purchased from. It also allows the manager to add new material received from the supplier. Supplier page gives the manager access to detailed information about each supplier the company is purchasing material from. It also allows the manager to add a new supplier to associate with the project/company.

Image 6 - Personnel Details page from ReCon Material application.

Personnel page provides detailed information about each personnel that is contractor/subcontractor who is associated with the project and actively working in the project. When the user clicks on the Personnel Detail button it also provides a list of material issued by that personnel, that enables the manager to keep track of each personnel and their material usage pattern. The manager can add new personnel to the database using this page to the project/company. This completed the development of the application using Knack Builder.

Evaluation

Technology before being released for everyone needs to be tested, evaluated and reviewed by programmers, developers and software testers. Usually, a beta version is released and send out for few people to test the application and fix any bugs that may surface. Since we used an app builder, Knack helped us to avoid technical and development issues. We needed the app to be evaluated by students and industry personnel.

Once the application was completely developed, it was sent out to peers, colleagues and some industry professionals to use and evaluate for the usability, future scope, and limitations. Due to lack of time, the evaluation period for the application was short, but as the app was evaluated by the people familiar with construction technology and processes, we had a targeted group.

Questions were asked for the evaluation of the application such as How easy is the app to understand? Did you find the app useful? Is the problem stating an actual issue that the construction industry is facing? Does the app provide an adequate solution for the problem stated? What can be done to improve the app, comments, and feedback?
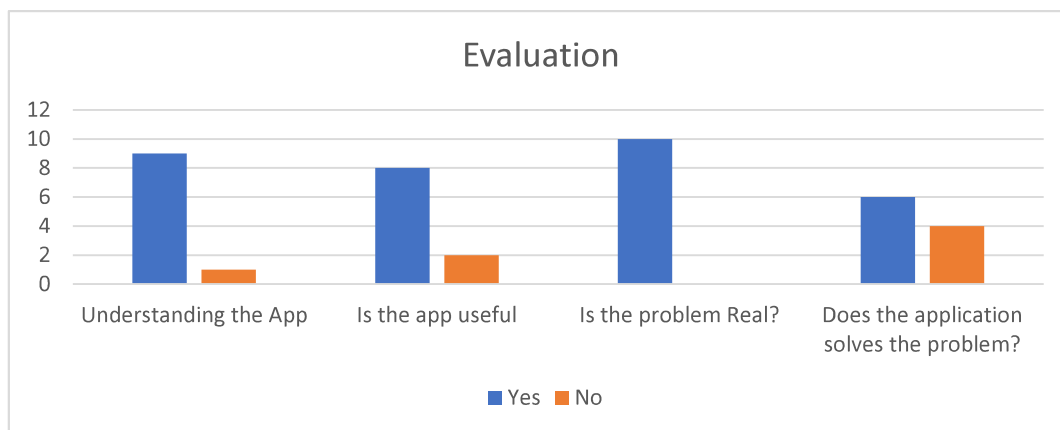

Chart 1: Illustration of Evaluation

The major positive that we received was the simple yet intuitive features of the application. Everyone found the interface simple to understand and work with. The idea behind the application and the purpose of the application was appreciated and validated as a problem we are facing in the industry. There was some feedback on how the application can be improved while retaining the purpose of the same. adding material cost to the application to keep track of material budget of the project and cost controls, adding inventory capacity to the application for each material to not overflow the inventory, etc. were some of the comments received after the evaluation of the application.

Discussion

Construction innovation occurs incrementally over a period of many years, and as a consequence, is often invisible. Regardless of its conservative reputation, the construction industry does innovate and adopt technological change, nonetheless slowly (Tangkar & Arditi, 2004). The online database application development platform we used is new to the construction industry professionals, and they are not likely to actively use them. A detailed analysis of the pros and cons, opportunities and the risks of the developing tools will encourage conservative construction professionals to confidently decide whether to apply these new tools to their projects. The table below SWOT analysis of the application which will draw a logical discussion of the new development tools among construction professionals.

Strengths	Weakness
• User-friendly interface. • Easy to understand and execute. • Tracking and Accountability of material through inventory. • Effective for cost controls of material budget and reduction in material waste.	• The application still in beta test. • Limitations to work for big projects. • The absence of cost information for material budgeting. • The absence of project schedule resulting in a lack of information for material requirement forecasting.
Opportunity	Threats
• Can target smaller projects and companies with a low budget. • The future scope of the application is limitless. • Can be used for cost controls with future developments. • With the implementation of project schedule, better tracking and prediction of material requirement.	• Uncertainty associated with new technology. • Major software companies can release their own version of the same. • No distinctive characteristics that cannot be duplicated. • Irrelevant for bigger projects and companies.

Table 1 - SWOT analysis of ReCon Material application

Conclusion

Communication is one of the major attributes of the construction industry. Being one of the most complex and intensive industry, a lot of information and data is being shared among different personnel at any given time during a project. This flow of information should be uninterrupted, clear and precise. Material management is one of the important aspects of the construction industry, as the industry loses a lot of revenue due to material wastage. This is wastage of material is not sustainable and environmentally unfriendly. Though many types of research have been conducted for the ratification of the problem, it remains a huge problem in the industry. This motivated us to develop the web-based application ReCon Material. This application was developed using Knack Builder, which is an online application developing platform.

The application, still in beta testing, worked as intended. It is tracking inventory effectively with the added feature of Activity and Material relationship. The manager will know what material is being issued for what construction activity. This also allows the manager to cross-check the issued quantity against estimated quantity and the reason why the extra quantity of material was used for a certain activity if any. This leads to ratification in the construction process to gain more productivity and a reduction in material wastage. It also helps in better estimation of the required material quantity. Over time, Cost and Schedule can be added to the application to increase the productivity of the application and make it more versatile.

References

Craven, D.J., Okraglik, H.M. & Eilenberg, I.M. (1994) Construction waste and a new design methodology. In Sustainable Construction: Proceedings of the 1st Conference of CIB TG 16 (ed. C. J. Kilbert), pp. 89-98.

Ferguson, J., Kermode, N., Nash, C.L., Sketch, W.A.J. & Huxford, R.P. (1995) Managing and Minimising Construction Waste - A Practical Guide. Institution of Civil Engineers, London.

Lanting, R.W. (1993) Stofstromen in de bouw en hef milieubeleid. In Ketenbeheer in de Bouw (ed. T. J. J. B. Wolters). Samson Bedrijfsinformatie, Alphen aan den Rijn. (In Dutch.)

Rogoff, M.J. & Williams, J.F. (1994) Approaches to Implementing Solid Waste Recycling Facilities. Noyes Publications, Park Ridge, NJ.

Brooks, K.A., Adams, C. & Demsetz, L.A. (1994) Germany's construction and demolition debris recycling infrastructure: What lesson does it have for the US? In Sustainable Construction: Proceedings of the 1st Conference of CIB TG 16 (ed. C. J. Kilbert), pp. 647-656.

Heino, E. (1994) Recycling of construction waste. In Sustainable Construction: Proceedings of the 1st Conference of CIB TG 16 (ed. C. J. Kilbert), pp. 565-572.

Fadiya, O. O., Georgakis, P., & Chinyio, E. (2014). Quantitative analysis of sources of construction waste. Journal of Construction Engineering, 1-9.

Dainty, A. R. F. & Brooke, R. F. (2004). Towards improved construction waste minimisation. Structural Survey, 22(1), 20-29.

Arif, M. Bendi, D., & Toma-Sabbagh, T. (2012). Construction waste management in India: an exploratory study. Construction Innovation. 12(2), 133-155.

Saez, P. V., Merino, M. R., Gonzalez, A. S. A., & Porras-Amores, C. (2013). Best practice measures assessment for construction and demolition waste management in building constructions. Resources, Conservation and Recycling, 75, 52-62.

Tangkar, M., & Arditi, D. (2004). Innovation in the Construction Industry. Civil Engineering Dimension, 96-103.

Knack Builder. (2018, September). Retrieved from Knack*:https//builder.knack.com/