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COMPARATIVE STUDY OF UNIFORMAT AND MASTERFORMAT FOR CONSTRUCTION COST ESTIMATING

Lu, Ming.[1, 2], Hasan, Tarequl[1], Hasan, Monjurul[1]
[1] University of Alberta, Canada
[2] mlu6@ualbera.ca

Abstract: Cost estimating is the core functionality of project planning pertaining to all the stakeholders in developing a project. UniFormat (UF) and MasterFormat (MF) are two commonly used project breakdown standards for guiding construction cost estimating throughout different stages of the project lifecycle. This study aims to develop a systematic framework to assist in applying UF and MF in estimating processes starting from conceptual planning to detailed estimating. The framework defines the application spaces of UF and MF and establishes the correlation between these two systems, which is conducive to estimating project costs without tediously building and altering project work breakdown structures (WBS). The framework's central concept is to take advantage of the WBS embedded in UF and the structured RS Means data to formalize the project preliminary WBS, thereby easing the search for MF items; at the same time minimal changes are required to develop the final project WBS. A simple garage project is used as a demonstration case to apply the proposed framework.

1 INTRODUCTION

A scientific approach to estimating construction cost is critical to perform economic analyses and evaluating project feasibility (Carr, 1990; O'Connor and Caraway, 1993), which entails defining the scope of the project and establishing the work breakdown structure (WBS). Formalizing the appropriate WBS is considered as the key to project planning and control. It is a process of decomposing the entire project hierarchically into major functional divisions and defining the total project scope (Globerson, 1994). It is also considered as a dynamic tool which provides the framework for detailed cost estimating and schedule development (Ibrahim et al, 2009). 'MasterFormat' (MF) and 'UniFormat' (UF) were jointly developed by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC), providing industry standards for establishing work breakdown and method specifications especially for building construction projects during different stages of its life cycle. In general, MF is applicable when detailed cost estimating is performed given detailed drawings and specifications are available. MF provides the formatting guide (e.g. titles and section numbers) for organizing data about construction requirements, products, and activities (masterformat.com, 2017).

Nonetheless, accurate project descriptions along with engineering drawings are generally not available during the preliminary project development phase. Preliminary project description is more conceptual due of lack of design details and specifications (Jrade and Alkass, 2002). At the initial stage for concept evaluations or budgeting purposes, estimators often cope with a wide range of cost variation due to unavailability of drawings and specifications. Dell'Isola (1998) maintained that the assembly based estimating (UF) provided the basis for project evaluation, engineering design, and cost budgeting in the early stage of the project. Moreover, the UF classification system also serves as a checklist for the creativity/brainstorming phase of the initial job plan, thus making the process more efficient and effective

(ASTM E1557-09, 2015). The main advantage of using UF lies in the organization of construction information by functional elements (assemblies) regardless of the methods and materials used to accomplish them (Charette and Marshall, 1999). In this case, UF is taken as a more relevant estimating guide based on commonly seen assemblies of a building.

Although the application domains of UF and MF are largely regulated by the maturity of the project description, both UF and MF follow the common strategy in scoping and defining a project. In either case, the project specific WBS is the key to structuring all the detailed information of a construction project and organizing available data and practical knowhow.

On the other side, a reliable itemized source of construction cost data is essential for preparing a credible project cost. *RS Means* provides well established commercial construction estimating databases and widely utilized by practitioners in developing project estimates (Lu and Liu, 2004). RS means stores cost data including material cost, labor crew rates, equipment rates, and productivity and market variations in a well-structured format that is compatible with UF and MF.

When the purpose is to make a conceptual cost budget for feasibility study or economic evaluation on a building construction project, RS means cost data organized by UF are applicable. RS Means cost data organized by MF is relevant to detailed cost estimating. Note both processes follow the similar strategy and utilize standardized project WBS (UF/MF) along with well-structured RS Means cost data, there is a need to make a common framework which guides the application of both in different stages of the same project. This study proposes an integrated framework for estimating the construction cost at concept and bidding stages of the project development lifecycle. The main advantage of this framework is to minimize the variation in WBS intended for different stages of the project while clearly accounting for the variations. In the proposed framework, an assembly based estimating formed as per UF in the conceptual stage of a project will facilitate the selection of exact items within MF. Note, MF contains a large volume of detailed information (50 divisions and around 6,500 total items) and hence is overwhelming to inexperienced users. UF indeed provides much needed guidance to assist estimators in the use of MF and the search of MF items. In the remainder of this paper, the correlation between the two is mapped out and the relative cost ratios are determined, illustrated with a case.

2 UNIFORMAT AS ROADMAP TO NAVIGATE MASTERFORMAT

2.1 Proposed Framework

In the proposed framework, UniFormat (UF) serves as a consistent basis to structure the primary project description and classify the total building project into key cost elements (called “Assembly” estimate in RS Means). The cost breakup data in RS Means for UF-based assembly estimate assists in the development of a preliminary WBS for setting up MF “Unit” estimate in RS Means. Later this preliminary WBS can be refined into the final WBS given detailed project information available, thus significantly simplifying the process of building a MF-compatible detailed cost estimate in RS Means. Given no major changes as the project evolves into the detailed engineering stage, the initial WBS developed from UF-based cost breakup can be used to generate the final WBS. This helps a beginner in searching the desired item in less time within MF; for an experienced estimator, it would save a lot of time in developing the final estimate. During this processing, alterations of the preliminary WBS are generally required as per updated project specifications. If the project needs considerable modification, then it is advisable to update assembly based estimate with the most updated information prior to developing the final WBS for MF-based estimating. The illustration in Figure 1 shows the schematic view of the proposed framework for transforming the preliminary WBS generated from UF to the final WBS.

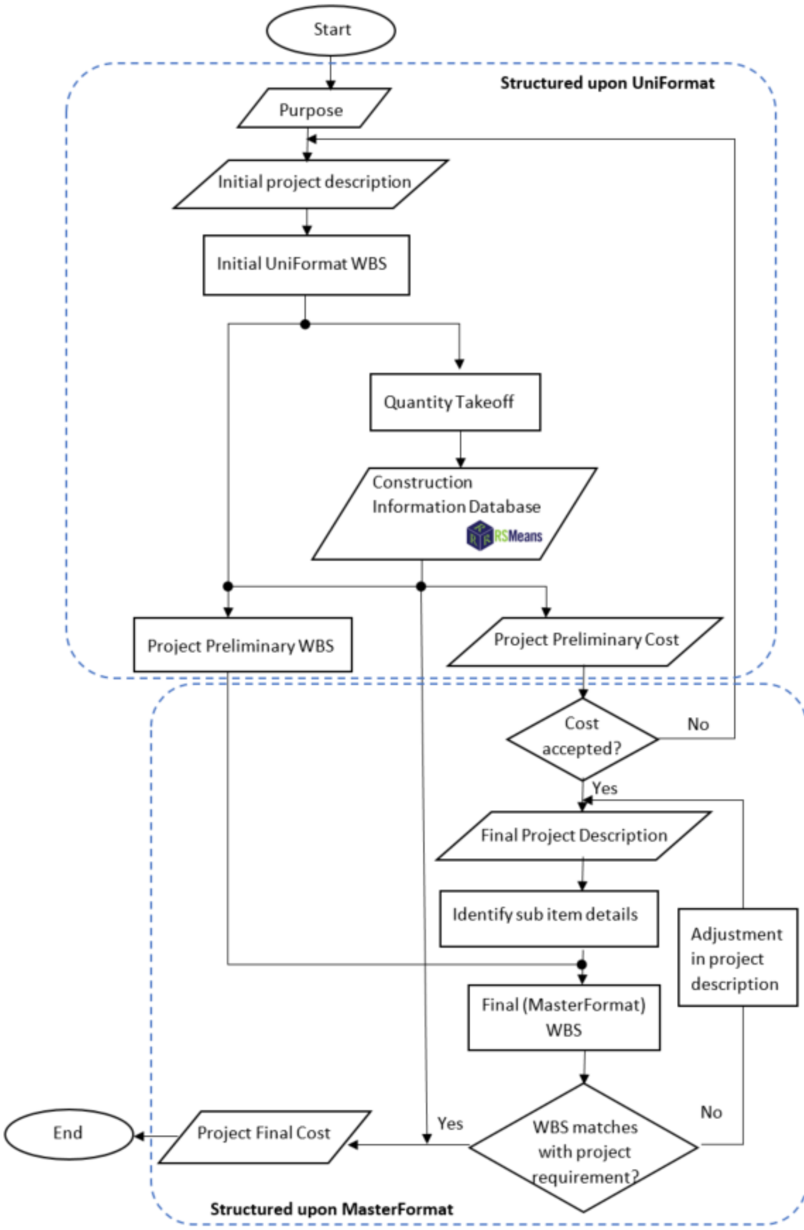

Figure 1: Flowchart to show the proposed framework for developing project WBS and estimating cost.

2.2 Validation of the Framework

In this section, the functional demonstration of the proposed framework is described with a case study based on a simple garage project. Herein, the initial information is processed following five major steps (Fig. 1).

Step 1. Initial cost breakdown by identifying major components is prepared based on the available initial information of the project (Initial UF WBS in Figure 1).

Step 2. With the help of the RS Means database, cost of the relevant sub-items of each major component is identified for estimating the preliminary cost of the project.

Step 3. Finalize the Project preliminary WBS integrating the sub item information from the RS Means.

Step 4. This preliminary WBS can be used to complete the project WBS (as MF guide) as per final project description.

Step 5. Project final cost can be estimated from the project final WBS based on MF.

The gist of the initial project description is given in Table 1.

Table 1: Initial project description.

1. The project is a single storied garage building with concrete floor and roof. The total gross area of that building is approximately 5,400 square feet (60'× 90') with 12' height.
2. The exterior CMU wall (concrete masonry unit) is made of 12" thick reinforced concrete regular-weight blocks with maximum reinforcement.
3. For the continuous reinforced wall footing, the load capacity is about 9.3 KLF.
4. The slab on grade is of heavy industrial 6" thick reinforced concrete.
5. There are three interior cast-in-place columns having 12" square size cross section and minimum reinforcement; the maximum load bearing capacity is 150K and the footing size is 6'×6'. The roof slab is a 9" thick flat concrete plate with a bay size of 25'x25'.
6. The roof slab is a 9" thick flat concrete plate with a bay size of 25'x25'.
7. There is a single 12'×12' steel door on one side of the building, featuring an electrically operated system that can roll in overhead.
8. There are eight windows with wood casement and insulated glass, the size of each window being 1'- 10" × 3'-2"
9. The allowable soil bearing capacity at the foundation is about 3KSF (Kip per square feet).

On our case study, following Step one of the proposed framework, project major cost items are identified as per initial project description and expressed as UF WBS. Figure 2 shows the hierarchical WBS of the complete project according to UF classifications. Total garage project consists of two major groups (Level 1 subdivisions), a. Substructure and b. Shell as according to UF classification, where these two are further subdivided up to Level 3.

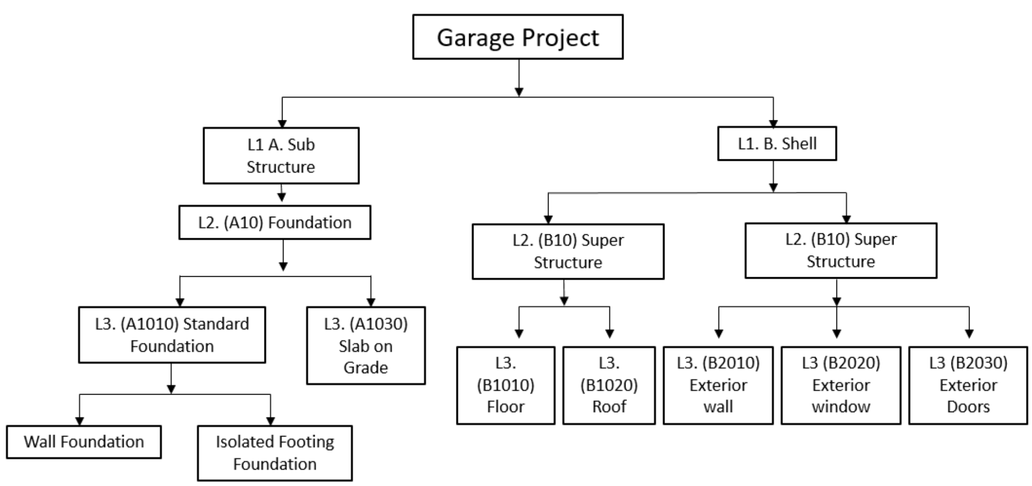

Figure 1: Project preliminary WBS as according to UF

On Step 2, the RS Means database is queried to find out the sub items under each major cost item (items listed on the initial UF WBS) making best match with preliminary project description. As an example, Figure 2 shows the detailed cost breakup as per the RS Means database in terms of an isolated footing – which is identified as a major cost item.

A10102103600 **Based on National Average Costs**

Spread footings, 6' - 0" square x 14" deep, 3 KSF soil bearing capacity, 100 K load

Description	Quantity	Unit of Measure	Material O&P	Installation O&P	Total O&P
C.I.P. concrete forms, footing, continuous wall,	12.00000	L.F.	14.61	52.73	67.34
C.I.P. concrete forms, footing, spread, plywood,	28.00000	SFCA	27.14	148.55	175.69
Reinforcing steel, in place, footings, #4 to #7, A	0.04000	Ton	52.76	37.25	90.01
Structural concrete, ready mix, heavyweight, 30	1.56000	C.Y.	333.19	0	333.19
Structural concrete, placing, spread footing, dir	1.56000	C.Y.	0	41.93	41.93
Concrete finishing, fresh concrete flatwork, floor	36.00000	S.F.	0	14.97	14.97
Excavating, trench or continuous footing, comm	36.00000	S.F.	0	36.07	36.07
Excavating, bulk bank measure, 1/2 C.Y. = 30 C	2.21500	B.C.Y.	0	20.15	20.15
Backfill, trench, 6" to 12" lifts, dozer backfilling,	0.66000	E.C.Y.	0	2.84	2.84
		Total	**$427.70**	**$354.49**	**$782.19**

Figure 2: RS Means cost and quantity breakup for single isolated footing work as per UF method based on U.S. national average cost (including 10% O&P)

As there are three isolated footings on this project, so that the total cost including 10% O&P will be 782.19 × 3 = $2,346.57.

On Step 3, the initial WBS is updated with subitem cost information from RS Means and a project preliminary WBS has finalized accordingly. The preliminary WBS (decomposition level 4) for isolated footing based on details of sub items is illustrated in Figure 3 as an example.

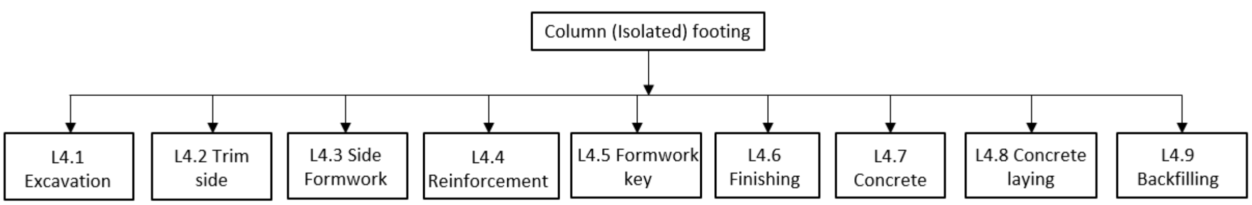

Figure 3: Project preliminary WBS for Column Footing

Step 4: Once the project preliminary cost model is accepted, the project description can be finalized with sufficient specifications as per project requirements. If the preliminary cost model is not accepted, then there is a need to adjust the project description by repeating from Step 1. The final project description for the present case study is presented in Table 2. Once project description is confirmed, sub item details can be sorted out and matched with the preliminary WBS.

Table 2: Final Project Description

1. The project is a one-story reinforced unit masonry garage building (60 ft wide×90 ft long×12 ft high).
2. The exterior load bearing walls are made of 12” thick 5000 psi CMU (concrete masonry unit) blocks. Vertical reinforcing consists of #6 bars every second block, with reinforcing cores fully grouted. All rebar extends 3 ft above the top of the wall and is bent into the roof slab.
3. The continuous wall footing will be 24” wide×18” deep with 2 #6 bars, continuous, and #4 bars, 18” on-center, across the footing. The footings are formed on the sides, using fine

graded earth as the soffit.

4. All concrete (ready mix) in the structure is 4000 psi, which is placed by crane and bucket.
5. The slab-on-grade (SOG) is 6" thick, with 6×6 6/6 welded wire fabric reinforcing. The subgrade
   will be 6” gravel, 3” sand, with a 0.010” thick polyethylene vapor barrier.
6. Three interior reinforced concrete columns are placed down the center line of the building. All columns are 16”×16” and are constructed using 1-use plywood forms and 4 #8 vertical reinforcing bars. Column footings are 6 ft square and are constructed using 1-use plywood forms, 15” deep, with 6 #6 bars each way in the bottom of the footing. Footings are formed on all sides, with fine graded earth as the soffit.
7. The roof slab is an 8” deep flat slab constructed using 2-use plywood forms; with #8 rebar 24” on-centre each way placed in the bottom of the roof slab; #4 bars, 12” on center each way, are located at the top of the slab in an 8ft square area over each column.
8. 1-use wood curb forms are used for the construction of the slab-on-grade and the roof slab.
9. One swing-up metal door (16' × 7') with weather stripping rubber is located in the center of the shorter wall in the east.
10. Four wood windows (34” ×22”) with insulated glasses are placed on each of the longer (horizontal) walls.
11. High chairs (3" high, plain steel galvanized) are spaced not over 6ft apart each way under the intersection of bars, are used to support the reinforcing in slabs and footings.
12. The maximum length of all types of rebar, except for welded wire fabric reinforcing, is limited to 20ft (laps are specified as 18 in.), and all the bars will be tied at each intersection by bag ties (16 gauge, plain, 4" long.)

Utilizing the finalized sub item details on top of the preliminary WBS streamlines the search procedure and this preliminary WBS can be refined into the MF-compatible WBS without much effort. If the project specifications match the preliminary WBS, then there is no need to change. For the current case, taking isolated footing (column footing) as example, the final MF-compatible WBS is presented in Figure 4 and comparison between the project primary WBS and project final WBS is presented in Table 3.

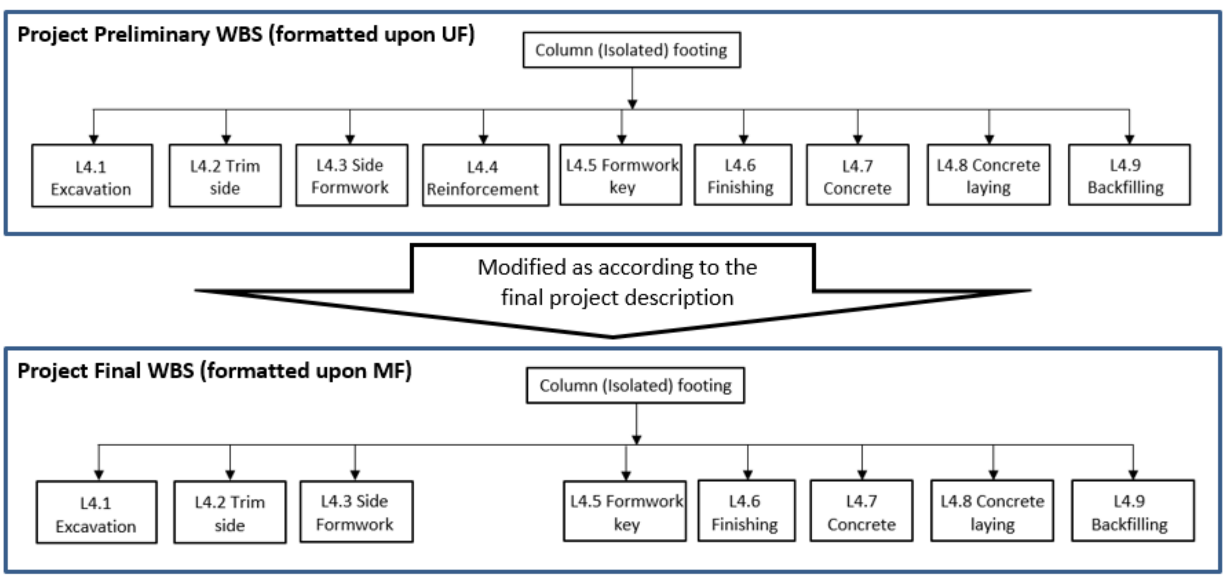

Figure 4: Modification of WBS for column (isolated) footing

On this current case, the final project WBS for column (isolated) footing is found almost the same as the project preliminary WBS except for one minor change: the item formwork key is removed on the final WBS since no requirement for formwork key is specified on the final project description.

Table 3: Sub item's description and unit comparison between UF and MF method for isolated footing item

ID	Item name	UF Details		MF Details			Remarks
		Units	Description	Line Number	Units	Description	
1	Excavating	BCY	Excavating trenches	31231616 6030	BCY	Excavating footings,	Excavation type change
2	Trim side	SF	Trim side by hand	31231616 1000	SF	Trim side by hand	Matched
3	Formwork	SFCA	Footing plywood, 4 use	03111345 5150	SCFA	Footing, plywood, 4 use	Matched
4	Formwork key	LF	Formwork accessories,	-		-	There is no requirement of formwork key.
5	Reinforcing	Lb	Reinforcing, #4to#7, grade 60	03211160 0500	Lb	Reinforcing, #4to#7, grade 60	Matched
6	Concrete	CY	Ready mix, 3000 psi,	03311335 0300	CY	Ready mix, 4000 psi,	Strength is changed
7	Concrete placing	CY	Placing with direct chute	03311370 2500	CY	Placing with crane and bucket,	Method of placing is changed
8	Backfilling	ECY	Dozer backfilling, compaction	31231613 3020	LCY	Trench backfill,	Method, unit and compaction are changed
9	Concrete Finishing	SF	Surface finishing	-		-	There is no requirement for concrete surface finishing
10	Curing		-	03391350 0015	SF	Curing, burlap	Curing item
11	Reinforcing accessories		-	-		Bag ties, High chairs	Reinforcing accessories

On Step 5, when the final WBS is defined, the final project cost can be determined based on the MF-compatible cost database such as RS Means. The search process on RS Means will be much simpler, as the project information are readily structured in the form of project final WBS that is aligned with MF.

3 COST COMPARISON

The final estimate for the total garage project is presented in Table 4. It is expected that there will be some differences between project preliminary cost (estimated form UF-based project preliminary WBS) and project final cost (estimated form MF-based project final WBS) because estimate is prepared at different stages of the project lifecycle factoring in different levels of project detail and information. Besides, the estimators start the estimating with a wide scope of possible options, but at the final stage, it narrows down to specific choices. There are some key reasons that account for this difference, namely: 1) methods of installation and 2) location of material use, 3) equipment use. Given the same quantity of work, the installation/execution method can vary, e.g. placing concrete can be done by pump or by crane and bucket or even by a direct chute, likely resulting in a wide variation of cost. In addition, material installation locations such as roof, wall, and locations for rebar installation and the number of reuse for formwork all lead to differences in resulting estimates.

Based on the results presented in Table 4, it can be said that without considering the quantity change while the construction methods do not differ much between initial and final estimating, the proposed frame work results in a very good approximation of the MF based final cost at the initial stage (88 %).

Table 4: Total cost comparison between two methods

Name of item	MasterFormat ($)	UniFormat ($)	Factor MF/UF
Wall Footing	22,533	19,833	1.14
Footing	2,684	2,347	1.14
Slab on Grade	40,508	93,312	0.43
Column	3,565	2,588	1.38
Roof slab	112,109	93,528	1.20
Block wall	71,294	70,632	1.01
Door	2,784	6,241	0.45
Window	2,494	5,167	0.48
Total	257,971	293,649	0.88

4 CONCLUSION

This study presents a novel framework to develop the project preliminary WBS by taking advantage of the UF building project classification system and the RS Means cost data. The use of this preliminary WBS is not just limited to preparing the project preliminary cost estimate; it serves as an effective guide for preparing the MF based project WBS and final cost estimate. The proposed framework potentially eases the search effort by an estimator in preparing the final cost estimate, which entails significant efforts in identifying the proper references to a commercial cost database such as RS Means. Utilizing UF-to-MF conversion factors for guiding the estimating of future projects requires further application and generalization based on a considerably large quantity of projects. Future research efforts also include the automatic generation of WBS and finding the close match items or near match options in UF or MF information systems, so to make the process more intelligent and automated. Some other challenges regarding WBS generation and generalization of conversion factors between UF and MF cost estimates in estimating project cost are summarized as follows:

- In RS Means, the cost breakup data for UF estimating provides information based on U.S. national average cost, only summary cost is city-specific.
- In terms of UF estimating by the RS Means online system, instead of providing the ‘As Build Assembly Components’ items, if there is an option to customize breakup items in assembled components, then cost difference between UF and MF method can be reduced.
- The scope of the studied data is limited to small building construction, which needs to be verified for infrastructure projects like roads, tunnels, dams, and bridges.
- During detailed estimating analysis, the quantity takeoff does not consider any materials wastage in the present case study.
- Regardless the same quantity between initial and final estimates the cost difference may increase due to change of specifications or method of installation.

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