A Strategy for Reducing Material Waste of Ready-Mix Concrete Production Through Analytical Hierarchy Process (A Case Study)

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Abstract

Material waste is one of the serious problems in making ready mix concrete. Efforts to reduce the material waste will help companies increase profits and reduce material costs as well as production processes effectivity that have an impact on the products quality. This is a case study in PT Waskita Beton Precast, the purpose of this study was to determine the causal factors and how to reduce those in order to reduce material residuals. The method used is Analytic Hierarchy Process (AHP) with respondents that related to the ready-mix concrete production. From the pairwise comparison and weighting rank results show that strategy that should be chosen is developing quality of work process (0,499) which involves production function (1,711). Therefore, production function which covers throughout production control has the most priority to develop so that material cost will diminish as the cutting material cost (1,430) is one of best plans. Significant factor such as proper material handling will enhance its strategy performance since it has the highest rank (0,330) and correlates with proper material usage-storage-movement.

Keywords
waste material, decision making, analytic hierarchy process, ready mix concrete, developing of work process quality.

1. Introduction

Indonesia's economic growth in the first quarter of 2018 reached at 5.06%, and the construction sector was the main contributor of this vast increasing. The Central Statistics Agency of Indonesia (BPS) noted that the contribution made from the construction sector reached 0.72%, which was the second largest contribution after the manufacturing sector (0.97%). Concrete production dominated the chain of business production in construction companies, especially the ready-mix concretes. Ingredients of ready-mix concretes were simple, such as cement, sand, stone ash, split, water, and additives, each of which will be mixed based on the Job Mix Formula in the Batching Plant Operation (BPO). But on the other hand, its production process was quite complicated and often resulted excessive waste (Sangiorgio et al. , 2018) which can be shown by the gap of target and actual number of sand materials. Meanwhile high prestigious construction company had to carry out operational process efficiently, by diminishing the gap, in aiming increased profit (Ribera et al., 2020). Usually, the concrete production consisted of four steps : material preparation; material processing; finished concrete mixing; and final products shipping. These all steps may cause material that wasted or unintentionally wasted (Darko et al., 2019; Zhang et al., 2019). Concrete manufacturers, which also supported to construction business, often deal with the way to process concrete effectively. Mismatching production of ready-mix concrete can cause 38% of loss in construction business (Darko et al., 2019). Because the problem of selecting appropriate strategy based on various environmental factors also both subjective and objective point of views, therefore it should be considered to apply a multi-criteria decision making assessment. According to previous researches, several factors that linked to arising number of material waste were residual factors due to unused or wasted material, design factors that linked to material characteristics and trial-error of mixing, material handling and storage, and lack of precise material procurement (Darko et al., 2019; Ribera et al., 2020; Sangiorgio et al., 2018)

An AHP method is used to help decision makers in concrete manufacturers to select the most proper method to minimize material wastes from the initial phase (material preparation) until finished concrete pouring during the ready-mix concrete production considering the most significant actor, mission, and department. The main purpose of this study was to select the best method to minimize waste of material on the making of ready-mix concrete in PT. Waskita Beton Precast using AHP. In this study, criteria affecting the strategy for reducing material wastes during the ready-mix concrete production.

2. Literature Review

2.1 Material Waste

In Batching Plant Operation, according to standard operation procedure of ready-mix concrete production, there were four steps : 1. Production Order; 2. Material Preparation; 3. Material Processing (weighting, mixing, casting); 4. Material Shipping. Througout production process, every phase had potential occurances that can generate material waste (Ribera et al., 2020). Illustration can be seen in the Picture 1 below :

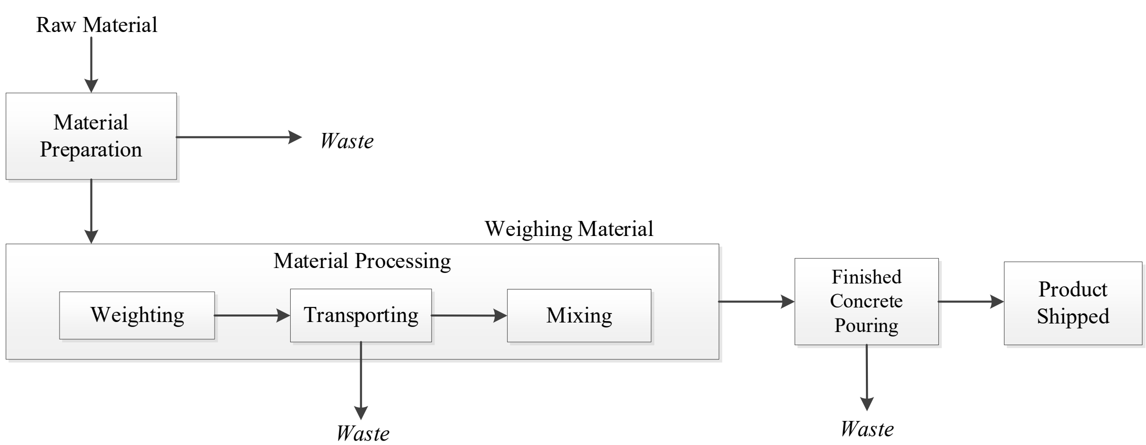

Figure 1. Ready-Mix Concrete Production Flow (Ribera et al., 2020)

Material waste emerged due to various factors such as Mismatch Design, Unproper Material Procurement, Inappropriate Material Handling/Storing, Undesirable Execution due to Environment and Implementation (Sangiorgio et al., 2018). In addition, there are also division and people as actors who involved in emerging material waste, explained below :

- Logistics function : including procurement preparation, material stock monitoring (daily), material in-out recording, material notes (accepting and shipping), sending purchase order to head of procurement, and quality assurance of incoming material.
- Production function : responsible for controlling activities during production process including scheduling production order, arranging mixer truck route, giving instructions to batching plant and wheel loader operator to run daily production according to standard operating procedure-design-and quality, maintaining wheel loader in good condition.
- Technical and Quality function : responsible for minimizing defects and overall product quality throughout production process including monitoring raw material qualities from supplier, checking specification and quality of materials in daily basis, reporting hardness quality, implementing slump test before shipping the products, monitoring concrete quality before releasing from batching plant.

Beside several factors and actors that influenced material waste, there were also various action plans such as optimizing workplace and storage system, developing products quality which including set up the process-design-and management for better target achievement, and material cost efficiency which including diminishing dissipation due to unplanned order or improper design (Darko et al., 2019).

2.2 Analytical Hierarchy Process (AHP)

AHP is one of decision making methods that consists of three parts : 1) identifying and organizaing decision targets, criteria, constraints, and alternatives into hierarchy; 2) evaluating pairwise comparisons between relevant elements at each level of hierarchy; 3) synthesizing using the solution algorithm of the result of the pairwise comparisons over all levels (Goepel, 2019; Saaty & De Paola, 2017). This method is effective for both subjective and objective evaluations, with the help of expert judgements and predetermined measurements. Between various multicriteria decision-making methods (MCDM) that implemented a more efficient and transparent selection within alternatives, AHP is broadly tested in literatures for the resolution of different decision-making problems. Moreover, AHP allowed selecting the optimal alternative between multiple options based on multiple evaluation criteria. In details AHP can be applied through seven consecutive steps : 1) Structuring the criterias and sub-criterias that related to problem evaluation; 2) Weights estimate of each criterion; 3) Verifying the mutual consistency between all weighted attributes from consistency ratio or CR (CR < 5% for n=3, CR < 9% for n=4, CR <10% for n>4); 4) estimates of the alternatives with respect to the individual criteria; 5) total scores and ranking alternatives, then analysis the ranks starting from the highest score to the lowest one (Saaty & De Paola, 2017).

As proposed in this paper, AHP can be a significant tool in screening and prirotizing waste minimizing strategy indicators. The result of AHP assessment can be used by decision makers today and in the future. Until today, AHP has been widely used in extensive scopes such as project and technology evaluation, selection of suppliers and construction technology, capital and information systems projects, hospital investment, industry 4.0 critical success, and many more (Thanki et al., 2016; Abadi et al., 2018; Acharya et al., 2018; Akbar et al., 2020; Dos Santos et al., 2019; Şahin et al., 2019; Sangiorgio et al., 2018; Singh & Nachtnebel, 2016; Vojtek & Vojteková, 2019). It is still wide open for AHP implementation in the scope of construction especially concrete production.

3. Methodology

This is a case study that planned and conducted to solve the decision making problems regarding deciding the most appropriate method to produce ready-mix concrete with the most minimum number of material waste. Working group was established which consisted of thirteen engineers and two academicians. The engineers were working in the Batching Plant Operation. In addition, the academicians were experts in industrial manufacturing and managerial systems. Both engineers and academician worked on several literature reviews and observing the plant to capture actors, action plans, and significant factors as part of criterias and sub-criterias. The main AHP calculation consists of defining hierarchy model, pairwise comparison and consistency ratio, and weighting score as follows :

The Step of "Hierarchy Model" :

Strategy for minizing wasted material during in the concrete production and construction has been widely discussed in previous research with various type of criterias and sub-criterias, as depicted in the Table below :

Table 1. Factor-Actors-and Action Plans Criteria Used in the Study

Significant Factors	Residuals	(Darko et al., 2019; Sangiorgio et al., 2018)
	Designs	
	Procurement	
	Material Handlings	
	Execution	
Actors	Logistic and Expedition functions	(Darko et al., 2019; Kamaruzzaman et al., 2018; Sangiorgio et al., 2018)
	Production functions	
	Technical and Quality functions	
Action Plans	Optimizing Workplace and Storage	(Godoy, 2018; Kamaruzzaman et al., 2018; Sangiorgio et al., 2018)
	Cutting Material Cost	
	Developing Product Quality	

Alternatives were captured into three actions based on the literature reviews and interviews with the respondents. First, The Facility Re-Layout, it relates to relayoutting existing facility by diminishing handling distance to enhance productivity, eliminate idle time, and improve material handling. Second, developing quality of work process which considers to add numbers of skilled labor by giving more valuable training that inline with short and long term period goals. The last one, conveyor redesign that aims to give extra features surrounding the conveyor so that materials will not be splattered.

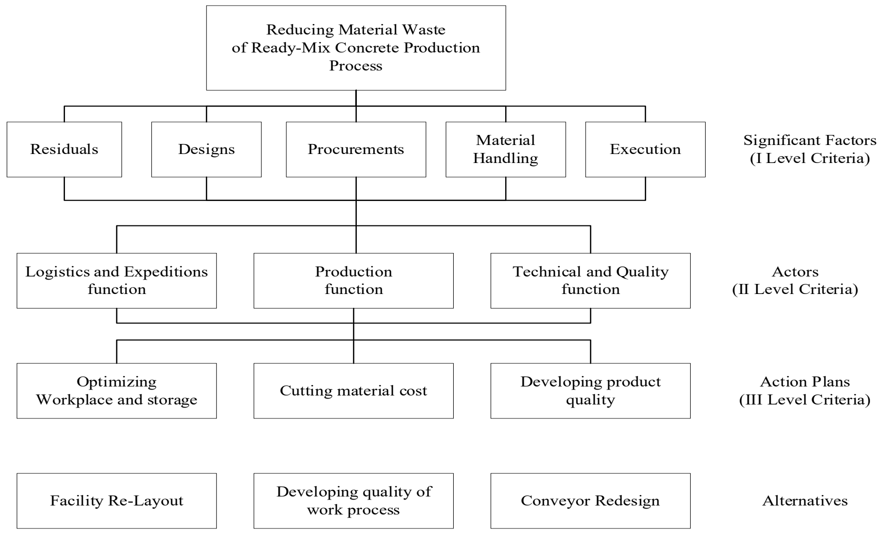

Figure 2. Hierarchy Model

The Step of "Pairwise Comparison and Consistency Ratio" :

Before entering comparison between criterias and alternatives, working group rated each criteria and alternatives. According to Saaty & De Paola (2017) the relative score from relative importance rate, provided by all member of working groups were calculated with geometric mean method and relative weight of the elements of each level was estimated. All comparison matrixes were analyzed to determine data consistency for every each item, consistency rate (CR) should be less than 0.10. Below is the Saaty scale that used in the relative importance rate :

Table 2. Pair Wise Comparison Scale for AHP

Intensity of Judgement	**Numerical rating**
Extreme importance	9
Very strong importance	7
Strong importance	5
Moderate importance	3
Equal importance	2
For compromise between the above values	2,4,6,8

CR derived from the ratio of the consistency of the results being tested to the consistency of the same problem evaluated with a random number. Therefore, CR calculated as : CR=CI/RI. Where CI (consistency index) is resulted from CI=$\frac{\lambda max-n}{n-1}$, meanwhile λmax is the largest eigenvector and the 'n' is the number of criteria or sub-criteria of each level (Goepel, 2019). Random index is selected from Table below :

Table 3. Consistency Ratio Random Number Index

Size matrix	1	2	3	4	5	6	7	8	9	10
Random index (RI)	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,51

Table 4. Pair Wise Comparison Of Three Subcriteria With Respect To Factors/Criteria

Pair wise comparison of three subcriteria with respect to factors/criteria				
Residuals	Logistic & Expeditions	Production	Technical & Quality	CI= 0.007 CR= 0.014 Priority weight
Logistic & Expeditions	1,000	0,858	1,348	0,336
Production	1,165	1,000	2,265	0,442
Technical & Quality	0,742	0,442	1,000	0,221
Designs	Logistic & Expeditions	Production	Technical & Quality	CI= 0.008 CR= 0.014 Priority weight
Logistic & Expeditions	1,000	0,577	0,693	0,241
Production	1,732	1,000	0,831	0,368
Technical & Quality	1,442	1,203	1,000	0,391
Procurements	Logistic & Expeditions	Production	Technical & Quality	CI= 0 CR= 0 Priority weight
Logistic & Expeditions	1,000	3,324	1,619	0,521
Production	0,301	1,000	0,481	0,156
Technical & Quality	0,618	2,080	1,000	0,323
Material Handling	Logistic & Expeditions	Production	Technical & Quality	CI= 0.006 CR= 0.011 Priority weight
Logistic & Expeditions	1,000	1,442	1,122	0,382
Production	0,693	1,000	0,567	0,239
Technical & Quality	0,891	1,763	1,000	0,379
Execution	Logistic & Expeditions	Production	Technical & Quality	CI= 0.005 CR= 0.010 Priority weight
Logistic & Expeditions	1,000	0,258	0,458	0,145
Production	3,873	1,000	1,308	0,505
Technical & Quality	2,182	0,765	1,000	0,350

Table 5. Pair Wise Comparison Of Three Sub-Subcriteria With Respect To Actors/Subcriteria

Pair wise comparison of three sub-subcriteria with respect to actors/subcriteria				
Logistic & Expeditions	Optimizing Workplace and Storage	Cutting Material Costs	Developing Product Quality	CI= 0.001 CR= 0.001 Priority weight
Optimizing Workplace and Storage	1,000	0,567	0,301	0,166
Cutting Material Costs	1,763	1,000	0,585	0,302
Developing Product Quality	3,324	1,710	1,000	0,533

Pair wise comparison of three sub-subcriteria with respect to actors/subcriteria				
Production	Optimizing Workplace and Storage	Cutting Material Costs	Developing Product Quality	CI= 0.003 CR= 0.006 Priority weight
Optimizing Workplace and Storage	1,000	0,244	0,405	0,130
Cutting Material Costs	4,096	1,000	2,117	0,575
Developing Product Quality	2,466	0,472	1,000	0,295
Technical & Quality	Optimizing Workplace and Storage	Cutting Material Costs	Developing Product Quality	CI= 0.015 CR= 0.029 Priority weight
Optimizing Workplace and Storage	1,000	0,235	0,637	0,156
Cutting Material Costs	4,263	1,000	1,619	0,554
Developing Product Quality	1,570	0,618	1,000	0,290

Table 6. Pair Wise Comparison Of Three Strategy Alternatives With Respect To Aim/Sub-Subcriteria

Pair wise comparison of three strategy alternatives with respect to aim/sub-subcriteria				
Optimizing Workplace and Storage	Facility Re-Layout	Developing Quality of Work Process	Conveyor Redesign	CI= 0.032 CR= 0.062 Priority weight
Facility Re-Layout	1,000	4,096	2,768	0,621
Developing Quality of Work Process	0,244	1,000	1,442	0,201
Conveyor Redesign	0,361	0,693	1,000	0,179
Cutting Material Costs	Facility Re-Layout	Developing Quality of Work Process	Conveyor Redesign	CI= 0.003 CR= 0.007 Priority weight
Facility Re-Layout	1,000	0,276	0,530	0,150
Developing Quality of Work Process	3,620	1,000	2,466	0,589
Conveyor Redesign	1,886	0,405	1,000	0,260
Developing Product Quality	Facility Re-Layout	Developing Quality of Work Process	Conveyor Redesign	CI= 0.005 CR= 0.010 Priority weight
Facility Re-Layout	1,000	0,310	0,361	0,142
Developing Quality of Work Process	3,225	1,000	1,570	0,503
Conveyor Redesign	2,768	0,637	1,000	0,355

The Step of "Weighting Score" :

From the weighting calculation, it shows that from significant factors this study suggest that material handling concern (0.330) is the most important of all (residual, designs, procurements, and execution). Moreover, from actor point of view, production function has the highest score of local weight (1.711). Then, the most crucial action plan will be cutting material cost (1.430) since it has the highest rank between optimizing workplace/storage and developing product quality.

Table 7. Ranks of Categories

Hierarchy Level	Categories	Local Weights		Global Weights	
		Weights	Rangking	Weights	Rangking
Level 1	Residuals	0,202	2	0,202	7
	Designs	0,154	4	0,154	9
	Procurements	0,115	5	0,115	11
	Material Handling	0,330	1	0,330	5
	Execution	0,200	3	0,200	8
Level 2	Logistic & Expeditions	1,625	3	0,320	6
	Production	1,711	1	0,343	3
	Technical & Quality	1,664	2	0,337	4
Level 3	Optimizing Workplace and Storage	0,452	3	0,150	10
	Cutting Material Costs	1,430	1	0,480	1
	Developing Product Quality	1,118	2	0,369	2

Meanwhile, in the Tabel Ranks of Alternatives can be shown that from global weight the best strategy is developing quality of work process (0,499). Second best strategy is conveyor redesign (0,283) and the third one is facility re-layout (0,218). The strategy of developing quality of work process is mostly relating to development of human resource skill by training or mentoring.

Table 8. Ranks of Alternatives

Alternatives	Local Weight		Global Weight	
	Weights	Ranks	Weight	Ranks
Facility Re-Layout	0,913	2	0,218	3
Developing Quality of Work Process	1,293	1	0,499	1
Conveyor Redesign	0,794	3	0,283	2

4. Results and Discussion

Minimizing waste has been discussed in broad topics especially in sustainable construction development. Nonetheless, cutting the number of wasted material in concrete production, -inline with construction business- is still limited compare to strategy of robust concrete composition or mixture (Godoy, 2018; Zhang et al., 2019). In this study, strategy is strongly related to significant factors-actors-and action plan, which these three will have to work simultaneously. The weighting score shows that material handling has the highest score in the significant factors (0.330) which similar to previous study that revealed material movement as main factors in construction waste management performance (Li et al., 2014). In addition, production function is the top rank in actors qualification. It means, production function which covers overall activities througout the concrete production process (including quality assurance and consistency of implementation) must be considered in details. Production was also found as the most important matters in the improvement of manufacturing process (Hassan, 2013). Then action plans as the third level in the hierachy, is about what concerns or activities that should be strictly monitored. As can be seen in table 7, cutting material cost is the action plan that has to be implemented. Cost efficiency is directly proportional to waste reduction (Dos Santos et al., 2019; Hassan, 2013; Kamaruzzaman et al., 2018; Li et al., 2014)

According to weighting score, the best strategy to minimize wasted material is developing quality of work process which mostly relates to quality of human resources. To suceed improving process quality, one of significant factor must be prioritized which is material handling and storage. Operators in material handling and strorage need high skills to run basic operation such us material movement-usage-storage in a proper way. Since material handling also a potential part of arising number of wasted material, therefore all the procedures in this part should inline with standar operating procedures. Moreover, effective measurement to assess the activity performance is needed to be applied.

Prior to production, checking the requirements needs to be done to study the moisture level of the material so that the material specifications are in accordance with the requirements for use. Differences in specifications can result in concrete products that are produced too liquid or too solid. If this happens then in the production process the part must add a split / sand material to improve the texture of the concrete. Adding these ingredients can add unnecessary costs to the ingredients. Strategies for improving the quality of work can be an alternative to minimize this by conducting training to improve and develop workers.This findings similar to Kamaruzzaman et al., (2018) which stated that waste storage and facilities also played important role

5. Conclusion and Recommendation

Construction business, especially ready-mix concrete production, has been an essential to economic growth through its supporting for infrastructure developments. Ready-mix concretes with its robustness play role in various modern and high-rise buildings but often face misproduction that cause increasing the number of material waste. In line with chosing development of work process quality, manufacturers also must consider people and division that involve the production function so that overall production activities are in control. It will adequate the action plan to cutting the material cost since cost efficiency lies on precise material purchase plan and usage. In addition, significant factor that relates to material handling or storage must being considered carefully. Since this factors are usually consisting of basic operations in material movement, usage, and delivery which vulnerable of wasted materials. Although this study can be implemented to other similar manufacturer, further research development is needed. Future research should validate the categories in this study and then systems of self-assessment must be developed so the manucaturer can evaluates its strategy performance which will provide informations for making improvement.

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References

Abadi, S., Huda, M., Basiron, B., Ihwani, S. S., Jasmi, K. A., Hehsan, A., … Muslihudin, M. (2018). Implementation of fuzzy analytical hierarchy process on notebook selection. *International Journal of Engineering and Technology(UAE)*, *7*(2.27 Special Issue 27), 238–243. https://doi.org/10.14419/ijet.v7i2.27.12047

Acharya, V., Sharma, S. K., & Kumar Gupta, S. (2018). Analyzing the factors in industrial automation using analytic hierarchy process. *Computers and Electrical Engineering*, *71*, 877–886. https://doi.org/10.1016/j.compeleceng.2017.08.015

Akbar, M. A., Khan, A. A., Khan, A. W., & Mahmood, S. (2020). Requirement change management challenges in GSD: An analytical hierarchy process approach. *Journal of Software: Evolution and Process*, (January 2019), 1–31. https://doi.org/10.1002/smr.2246

Darko, A., Chan, A. P. C., Ameyaw, E. E., Owusu, E. K., Pärn, E., & Edwards, D. J. (2019). Review of application of analytic hierarchy process (AHP) in construction. *International Journal of Construction Management*, *19*(5), 436–452. https://doi.org/10.1080/15623599.2018.1452098

Dos Santos, P. H., Neves, S. M., Sant'Anna, D. O., Oliveira, C. H. de, & Carvalho, H. D. (2019). The analytic hierarchy process supporting decision making for sustainable development: An overview of applications. *Journal of Cleaner Production*, *212*, 119–138. https://doi.org/10.1016/j.jclepro.2018.11.270

Godoy, D. L. P. (2018). Application of the Fuzzy-AHP method in the optimization of production of concrete blocks with addition of casting sand. *Journal of Intelligent and Fuzzy Systems*, *35*(3), 3477–3491. https://doi.org/10.3233/JIFS-17729

Goepel, K. D. (2019). Comparison of Judgment Scales of the Analytical Hierarchy Process - A New Approach. *International Journal of Information Technology and Decision Making*, *18*(2), 445–463. https://doi.org/10.1142/S0219622019500044

Hassan, M. K. (2013). Applying Lean Six Sigma for Waste Reduction in a Manufacturing Environment. *American Journal of Industrial Engineering*, *1*(2), 28–35. https://doi.org/10.12691/AJIE-1-2-4

Kamaruzzaman, S. N., Lou, E. C. W., Wong, P. F., Wood, R., & Che-Ani, A. I. (2018). Developing weighting system for refurbishment building assessment scheme in Malaysia through analytic hierarchy process (AHP) approach. *Energy Policy*, *112*(February 2017), 280–290. https://doi.org/10.1016/j.enpol.2017.10.023

Li, Z., Shen, G. Q., & Alshawi, M. (2014). Measuring the impact of prefabrication on construction waste reduction: An empirical study in China. *Resources, Conservation and Recycling*, *91*, 27–39. https://doi.org/10.1016/j.resconrec.2014.07.013

Ribera, F., Nesticò, A., Cucco, P., & Maselli, G. (2020). A multicriteria approach to identify the Highest and Best Use for historical buildings. *Journal of Cultural Heritage*, *41*, 166–177. https://doi.org/10.1016/j.culher.2019.06.004

Saaty, T. L., & De Paola, P. (2017). Rethinking design and urban planning for the cities of the future. *Buildings*, *7*(3), 1–22. https://doi.org/10.3390/buildings7030076

Şahin, T., Ocak, S., & Top, M. (2019). Analytic hierarchy process for hospital site selection. *Health Policy and Technology*, *8*(1), 42–50. https://doi.org/10.1016/j.hlpt.2019.02.005

Sangiorgio, V., Uva, G., & Fatiguso, F. (2018). Optimized AHP to Overcome Limits in Weight Calculation: Building Performance Application. *Journal of Construction Engineering and Management*, *144*(2), 1–14. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001418

Singh, R. P., & Nachtnebel, H. P. (2016). Analytical hierarchy process (AHP) application for reinforcement of hydropower strategy in Nepal. *Renewable and Sustainable Energy Reviews*, *55*, 43–58. https://doi.org/10.1016/j.rser.2015.10.138

Zhang, L., Lavagnolo, M. C., Bai, H., Pivato, A., Raga, R., & Yue, D. (2019). Environmental and economic assessment of leachate concentrate treatment technologies using analytic hierarchy process. *Resources, Conservation and Recycling*, *141*(September 2018), 474–480. https://doi.org/10.1016/j.resconrec.2018.11.007

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