A Stakeholder-Based Assessment Model (SAM) For Resource-Efficiency Measures in the Construction Industry

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ABSTRACT

In recent decades, the shortage of natural resources like primary raw materials has increasingly shifted into the focus of public discussion and research. Especially in the resource-intensive construction sector the implementation of a circular economy can strongly contribute to a reduction of primary resource demand. Positive developments can be noticed already, but the desired goal of an effective circular economy is still not being reached. For instance, the usage of recycled raw materials as substitutes for primary resources could be significantly higher.

In order to implement the protection of resources in the construction sector, it is essential to assess resource-saving measures and their impact on conservations as well as stakeholder's motivation to implement them. For this purpose, a Stakeholder-based Assessment Model (SAM) is developed to provide recommendations for political actions and potent measures to foster the circular economy in the construction sector to increase reuse and recycling of construction materials. In SAM, relevant stakeholders are identified and their characteristics and preferences as well as the level of influence on each other are modelled and validated for Germany. Moreover, available resource-conserving measures concerning the construction sector are identified and related measures are grouped together. Thereupon the influence of measures on stakeholders and their willingness to take positive actions in terms of a circular economy have been investigated and modelled. Relevant model data has been gathered by intensive literature review, surveys and expert interviews.

The results show that measures regarding lifecycle oriented planning of buildings as well as the development of stakeholder cooperation are the most effective ones to save resources and to reduce the disposal of construction material. Furthermore, the results demonstrate that a leading role of public authorities is crucial to foster a circular economy.

Keywords: *waste management, resource-efficiency measures, stakeholder-based assessment model*

1. INTRODUCTION

In recent decades, the shortage of natural resources like primary raw materials has increasingly shifted into the focus of public discussion and research. Especially in the resource-intensive construction sector the implementation of a circular economy can strongly contribute to a reduction of primary resource demand. Positive developments can be noticed already, for example the quality assurance system for recycled construction materials in Germany, but the desired goal of an effective circular economy is still not being reached. For instance, the usage of recycled raw materials as substitutes for primary resources in building construction could be significantly higher.

In order to implement the protection of resources in the construction sector, it is essential to assess resource-saving measures and their impact on conservations as well as stakeholders' motivation to implement them. For this purpose, a Stakeholder-based Assessment Model (SAM) is developed to provide recommendations for political actions and potent measures to foster a circular economy in the construction sector that lead to increased reuse and recycling of construction materials.

2. SCOPE AND RESEARCH APPROACH

As resource usage is still quite high in the construction sector, this contribution poses the research question of how relevant stakeholders can be incentivized to reduce their resource consumption or increase the share of recyclables and recycling materials in their current practice? In order to achieve a rethinking on stake-holders' parts and to implement efficient resource usage and resource protection as an integral element of every construction, also certain aspects have to be considered by authorities: Who are the key stakeholders? What is their role in achieving that goal? What are the most effective measures to incentivize the relevant stakeholders? This holistic view on a problem is suggested by the systems approach by Arbnor and Bjerke. Therefore, the developed model has to consider not only the effects of measures on the environment but also on the entire stake-holder network. That means that the effects of internal objectives of stakeholders, their ability to influence resource protection and their influence on each other are also relevant factors in the system.

Therefore, in the following subsections current literature is reviewed regarding their ability to derive political measures and incentives for stakeholders based on analysis and simulation of stakeholder objectives, of economic effects on stakeholders and stakeholder interactions (See section 3). To answer the research question, a model (SAM) is developed in section 4 to evaluate resource-saving or resource protection measures (Political instruments) with regard to the addressed stakeholders and the related stakeholder interactions. For this purpose, several political instruments are evaluated not only by their economic effects but also by their ecological impact. Furthermore, the stakeholders' willingness to act according to the political measure is considered. To compare political measures with each other and to provide decision support for the respective authorities an effectivity value is calculated and recommendations are proposed. Then, the application of SAM in the German construction industry is described in section 5 and model results are shown and analysed. This is followed by a conclusion and an outlook on future re-search.

3. STAKEHOLDER ANALYSIS AND LITERATURE DISCUSSION

The enormous relevance of stakeholder management in the construction industry results from the higher number of stakeholders involved in building projects. Stake-holders follow different objectives and have different motivations. According to Kua, the stakeholders' willingness for pro-environmental behaviour is influenced by willingness conditioning factors such as incentives (given by policy measures or other stakeholders), responsibility and capability influence. The comprehension and consideration of their interests, needs and effects on a project can determine the success of a project. In order to comprehend outcomes of a system, also interdependences and influences within a system are of importance. Stake-holders are highly important as they might have essential information and expertise that are necessary for a project to succeed. Involving those and ensuring their support can help to avoid conflicts and failures. Summing up, stake-holder management helps to understand how applied measures and current situations are perceived und what it means for the project or initiative. There are several definitions for the term stakeholder. According to Mitchell et al., stakeholders are not only a moral, personal or financial interest group of a project or a company because they are affected by project's success or effects, but also those have to spend for instance resources in order to obtain those profits. Moreover, there can be stakeholders without any entitlement to any part of the success and are not affected in any way by its actions but who can still influence other stakeholders. For the purposes of this paper, the focus lies on the definition of Mitchell et. al.

The consideration of stakeholders in a model poses the challenge of quantifying mostly qualitative measures. Some already developed tools might be supportive for quantification and are described in the following. Johnson et al. have concluded that it is not sufficient to understand the needs and positions of stakeholders. Also, the ability and power to enforce their interests hast to be considered. At the same time interest can reflect the strength of their desire to enforce their position in a project. Bourne and Walker suggest a stakeholder circle to visualize stake-holders' power and influence within a project. However, in order to wholly un-derstand stakeholder decisions, it is important to consider their interest. Bourne and Walker go one step further by arguing that in addition the effects of interests have also to be considered. Therefore, they use the stakeholder Vested interest Intensity Index (VIII) to measure power.

$$\boldsymbol{ViII} = \sqrt{\frac{\boldsymbol{v} * \boldsymbol{i}}{\mathbf{25}}}$$

where, v = strength of personal interest in the project of a stakeholder, i = influence of a stakeholder and 25 = 5x5 (Both variables can be valued between 1-5)

Equation 1

Olander combines Bourne and Walker´s idea of the ViI with the power legitimacy urgency model by Mitchell et al. The latter claims that one should differentiate between stakeholders who have influence, independently of the legitimacy of their claims, and those stakeholders, who might have claims, whether justified or not, but who are, at the same time, without any power. Using both models as a basis, Olander suggests, that instead of measuring the power, it is better to measure its effects. He uses the position of stakeholders (Pos) according to McElroy and Mills and also the attributes (A) of the power-legitimacy-urgency-model by Mitchell et al. In addition, Olander applies the vested interest index in order to create a Stakeholder Impact Index (SII), which reflects what effects the stakeholder has on a company.

$$\boldsymbol{SII} = \boldsymbol{ViII} * \boldsymbol{A} * \boldsymbol{Pos}$$

where, A = Attributes and Pos = Position of Stakeholders

Equation 2

These methods provide valuable instruments for the measurement of stakeholder influence and are used in SAM (see section 4.3). At the same time, they pose a difficulty, as in construction there is no central company towards which the relation-ship can be analysed. For that reason, the analysis has to be extended to observe the whole network. It is not relevant in the analysed construction stakeholder net-work how a manager can interact with different stakeholders, but what the mutual interaction of stakeholders means for the set target. Knoeri et al. provides a structural agent analysis by an agent based modelling approach and applies it to the resource use in construction. However, in both approaches the relationship between the stakeholders and mutual influences are hardly considered. Thus, based on current literature the observation of measures' effects on the network is not possible yet. Therefore, in the following a stakeholder-based assessment mod-el (SAM) is developed.

4. DEVELOPMENT OF A STAKEHOLDER-BASED ASSESSMENT MODEL (SAM)

The depicted model consists of two parts. First, the network defines the constants of the model (Section 4.1). On the one hand, those are the success functions which reflect what is important for the different stakeholders. On the other hand, those are the relationships/ interactions between the stakeholders. Second, the effects of measures on the environment are considered. Here, a new way will be introduced to integrate those effects into the stakeholder model by developing the SAM.

4.3 Definition of stakeholder's characteristics

Firstly, stakeholders have to be identified and categorized. Stakeholders' needs, interests and motivations have to be understood. In order to do it in a comparative way, an objective function has to be elaborated, which reflects their targets and reflects achievements thereof. Secondly, the relationships between stakeholders have to be made obvious. According to the reviewed literature, their influence on each other and their influence on the group result - resource conservation in this case - was modelled. Thirdly, the possible measures have to be identified as well as their effect on the goal. Lastly, those steps have to be brought together into a corresponding model that enables the joint analysis of all factors.

A stakeholder-network comprises a set of rational stakeholders A= $\{a_1..a_i..a_j..a_n\}$ and a set of possible measures M= $\{m_1...m_k\}$. The first step is to determine how the stakeholders can be defined. As for any economically deciding stakeholder, it is assumed, that his economic success is of a great value for him. Diederichs suggests to use the balanced score card in the construction industry to evaluate target achievements and success. That means that the aspired success is not only defined by financial results, but also through customer orientation, process excellence, customer relationship as well as education and growth. Diederichs also integrates the environmental perspective into this evaluation of success. Finally, that results in the success function of a stakeholder Z_a (Equation 3). The weights of the success function are the basis for the following modelling approach in section 4.2.

$$Z_a = g_{fin_a} * fin_a + g_{cust_a} * cust_a + g_{process_a} * process_a + g_{dev_a} * dev_a + g_{env_a} * env_a$$

where, $\mathbf{fin}$ = financial success of stakeholder a, $\mathbf{cust}$ = customer satisfaction of stakeh. a, $\mathbf{process}$ = success of process design of stakeh. a, $\mathbf{dev}$ = development/ innovation success of stakeh. a, $\mathbf{env}$ = success of environmentally responsible behavior of stakeh. a, $\mathbf{g_{factor}}$= weight of the variables and has to be defined for each stakeh. a (sum of all $\mathbf{g} = \mathbf{1}$)

Equation 3

4.4 Impact of measures on stakeholders

Measures, executed by either process or environmental stakeholders, have an effect of $w_{m,factor_a}$ on the factors of the stakeholder's success based on the values in the balanced score card. To determine the total impact of a measure on the stakeholder's success $(w_{m,a})$ the various effects are weighted using factors weightings.

$$w_{m,a} = \mathrm{g}_{\mathrm{fin}_a} * \mathrm{w}_{m,\mathrm{fin}_a} + \mathrm{g}_{\mathrm{cust}_a} * \mathrm{w}_{\mathrm{m,cust}_a} + \mathrm{g}_{\mathrm{process}_a} * \mathrm{w}_{m,\mathrm{process}_a} + \mathrm{g}_{\mathrm{dev}_a} * \mathrm{w}_{\mathrm{m,dev}_a} + \mathrm{g}_{\mathrm{env}_a} * \mathrm{w}_{\mathrm{m,env}_a}$$

where, $\mathbf{w_{m,a}}$= Impact of measure m on stakeholder a, $\mathbf{w_{m,fin_a}}$= Imp. of meas. m on financial success of stakeh. a, $\mathbf{w_{m,cust_a}}$Imp. of meas. m on customer satisfaction of stakeh. a, $\mathbf{w_{m,process_a}}$ = Imp. of meas. m on process design of stakeh. a, $\mathbf{w_{m,dev_a}}$= Imp. of meas. m on development/ innovation success of stakeh. a, $\mathbf{w_{m,env_a}}$= Imp. of meas. m on environmentally responsible behaviour of stakeh. a.

Equation 4

Moreover, stakeholders can be influenced by measures with different intensities $s_{m,a}$.This value can be compared with the legitimacy value according to Mitchell et al. At the same time, it creates a certain urgency for their position and interest, which can motivate them to act and give more strength to their claims. Stakeholder's readiness to act or accept a measure is preliminary described as $B_{a,m}$. Interactions between the stakeholders are not yet included.

$$\mathbf{B_{a,m}} = \mathbf{w_{m,a}} * \mathbf{s_{m,a}}$$

where, $\mathbf{B_{a,m}}$ = Readiness to act or acceptance of stakeholder a while realizing measure m, $\mathbf{s_{m,a}}$ = intensity-level for the impact of measure m on stakeholder a

Equation 5

4.5 Formulation of SAM

In a network, stakeholders decide dependently or independently from each other. Depending on the effects of measures on their own business, they influence other stakeholders to act in a certain way. This influence of stakeholder $\boldsymbol{a_i}$ on stakeholder $\boldsymbol{a_j}$ in dependence of measure $\boldsymbol{m}$ is quantified by $\boldsymbol{E_{a_i,a_j}(m)}$

$$\boldsymbol{E_{a_i,a_j}(m)} = \mathbf{w_{m,a}} * \mathbf{s_{m,a}} * \mathbf{e}_{a_i,a_j}$$

where, $\mathbf{E_{a_i,a_j}(m)}$ = Influence of stakeholder $\mathrm{a_i}$ on stakeholder $\mathrm{a_j}$ in dependence of measure m, $\mathbf{e_{a_i,a_j}}$ = General level of influence of stakeholder $\mathrm{a_i}$ on stakeholder $\mathrm{a_j}$

Equation 6

The influence of other stakeholders on a stakeholder create an additional readiness to act which is caused for example by neighbourhood effects, voluntary commitments and market adaption, image or competitiveness reasons. Therefore, an additional (Dis)motivation for the stakeholder's readiness to act is considered (Equation 7) based on the average mutual stakeholder influence $\mathrm{E}_{\mathrm{a_i,a_j}}(\mathrm{m})$ and the general level of influence $\mathrm{e}_{\mathrm{a_i,a_j}}$ of two stakeholders $\mathrm{a_i}$ and $\mathrm{a_j}$.

$$\boldsymbol{Infl_a}=\frac{\frac{1}{n}\sum_{i,j=1}^{n}(\,E_{a_i,a_j}(m)\,)}{\frac{1}{n}\sum_{i,j=1}^{n}(e_{a_i,a_j})}$$

where, $\mathbf{Infl_a}$ = Additional readiness to act/ acceptance of stakeholder a, n = total number of stakeholders

Equation 7

Since the optimization of success (formulated by their respective objective) is the foremost goal of any stakeholder, it has to be considered, that the success factors affect the readiness to act stronger then the influence $Infl$ does. Accordingly, $B_{a,m}$ is expanded to:

$$\mathbf{B_{a,m}}=\frac{\mathbf{Infl_a}+2\ \mathrm{w_{m,a}}*\mathrm{s_m}}{3}$$

where, $\mathbf{B_{a,m}}$ = Readiness to act or acceptance of stakeholder a while realizing measure m, $\mathbf{Infl_a}$ = Additional readiness to act/ acceptance of stakeholder a

Equation 8

The magnitude of a possible effect of the measure on conservations of resources is named l_{m_k}. In a general case, when all data is available, l_{m_k} includes economical, ecological and social aspects of sustainability.

The effectivity of a measure is defined as the impact of a measure on the protection of resources. The effectivity of a measure *Eff*(m_k) depends on the influence of each stakeholder on resource conservation and on the strength of stakeholders' readiness to act. Referring to the introduced structure of *Vill* (Equation 1), the effectivity of a measure consists of the effect of a measure on environment (effect of the interest $l_{m_k} * r_{a_i}$), and the readiness to act (Interest B_{a_i,m_k}). By averaging those values, a joint effectivity is calculated by:

$$\mathbf{Eff(m_k)}=\frac{1}{\mathrm{n}}\sum_{\mathrm{i=1}}^{\mathrm{n}}\sqrt[3]{\frac{(\,\mathbf{l_{m_k}}*\mathbf{r}_{a_i})*\mathbf{B}_{a_i,m_k}}{250}}$$

where, ***Eff***($\boldsymbol{m_k}$) = Effectivity of the measure $\mathrm{m_k}$, $\mathbf{l_{m_k}}$= Impact of the measure $\mathrm{m_k}$ on the conservation of resources, $\boldsymbol{r_{a_i}}$ = Influence of stakeholder $\mathrm{a_i}$ on the conservation of resources, $\mathbf{B}_{\boldsymbol{a_i,m_k}}$= Readiness to act or acceptance of stakeholder $\mathrm{a_i}$ while realizing measure $\mathrm{m_k}$

Equation 9

5. APPLICATION OF THE MODEL AND RESULTS

In this section, SAM is applied to the construction industry. Therefore, various current and future resource-saving measures in the construction industry have been analysed and grouped together to sets of measures. In total, 21 sets of measures have been created (see Figure1). Based on surveys and expert interviews with identified stakeholders and detailed literature research, the parameter values for the model were acquired. For this purpose, nine stakeholders of different stakeholder types (builders, department of the environment, architects, constructions engineers and demolition and recycling companies) were interviewed with a survey. The influence of resource saving measures on stakeholders have been evaluated with points in the range of [-2;2]. The influences between different stakeholders have been evaluated with points in range of [1;5]. In general, all sets of measures in the right upper right quadrant of Figure 1 should be preferred as they contribute the most to a conservation of resources and show a high effectivity as well as a high readiness to act. Sets of measures with the highest effectivity are such as set 12 (need to develop cooperation's between the stakeholders), set 18 (necessary improvement of the image of recycling construction materials), set 6 (stronger awareness of resource efficient construction) and set 2 (reducing barriers for resource-efficient behaviour).

The sets of measures 8, 12, 15, and 18 in the upper right quadrant have the highest readiness to act/ acceptance. With set 8 (need of stronger investments for resource efficient research) and set 15 (importance of a high quality in construction to extend the life cycle of buildings).

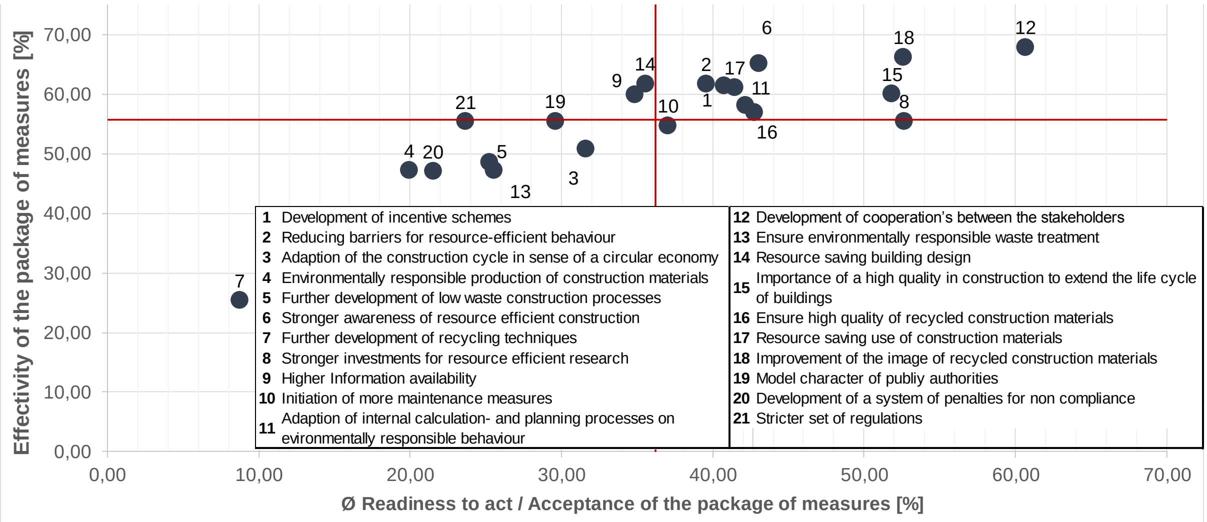

Figure 1: Effectivity Eff($\boldsymbol{m_k}$) of the sets of measures and stakeholder's readiness to act/ acceptance of the measure

Furthermore, based on literature research, survey and interviews it became obvious that the public sector has the highest influence on other stakeholders in the construction sector with respect to their resource-saving decision making. Specifically, it became clear that the public sector must take the leading role, whether in the form of incentives, or the removal of barriers. In particular, the leading role of the public sector in its own resource-saving actions is of central importance, e.g. by explicit preference for RC materials in public construction tenders.

6. SUMMARY AND DISCUSSION

In this contribution, a stakeholder-based assessment model is developed to evaluate the effect of political resource-saving or resource-supporting measures and to provide decision support to public authorities. The model is applied for a stake-holder network in the construction industry in Germany. Main results are that additional cooperation between stakeholders could be beneficial, the image of recycling materials has to be improved and barriers for resource-saving construction (materials) should be reduced. Furthermore, the public sector has a leading role with respect to the usage of recycling materials. To further improve the model results, interviews and surveys will be performed in the construction sector to detail the modelled stakeholders. Furthermore, the ecological effect of a resource-saving set of measures or single measures have to be related to resulting mass flows to better evaluate the impact on the environment. And, the consideration of interdependence of the measures themselves (a measure might be more successful, if another measure has been adopted) and the integration of rebound effects could be promising in future research.

REFERENCES

[1] Arbnor, I. and Bjerke, B. (2009), Methodology for creating business knowledge, 3rd ed., Sage, Los Angeles, London.

[2] Atkinson, G. (2008), "Sustainability, the capital approach and the built environment", Building Research & Information, Vol. 36 No. 3, pp. 241–247.

[3] Binder, C.R. (2007), "From material flow analysis to material flow management. Part II: The role of structural agent analysis", Journal of Cleaner Production, Vol. 15 No. 17, pp. 1605–1617.

[4] Bourne, L. (2010), Stakeholder relationship management: Using the Stakeholder Circle meth-odology for more effective stakeholder engagement of senior management.

[5] Bourne, L. and Walker, D.H. (2005), "Visualizing and mapping stakeholder influence", Man-agement decision, Vol. 43 No. 5, pp. 649–660.

[6] Cleland, D.I. (1995), "Leadership and the project-management body of knowledge", Interna-tional Journal of Project Management, Vol. 13 No. 2, pp. 83–88.
construction. An empirical study to address research gaps in previous studies", International Journal of Project Management, Vol. 29 No. 7, pp. 900–910.

[7] Diederichs, C.J. (2012), "Bauwirtschaft und Baubetrieb", in Zilch, K., Diederichs, C.J., Katzen-bach, R. and Beckmann, K.J. (Eds.), Handbuch für Bauingenieure: Technik, Organisation und Wirtschaftlichkeit, 2., aktualisierte Auflage, Springer, Berlin, Heidelberg, pp. 379–965.

[8] Freeman, R.E. (2010), Strategic management: A stakeholder approach, 2nd ed., Cambridge Univ. Press, Cambridge.

[9] Harding, R. (1998), Environmental decision-making: The roles of scientists, engineers, and the public, Federation Press.

[10] Johnson, G., Scholes, K. and Whittington, R. (2006), Exploring corporate strategy, 7th ed., Financial Times Prentice Hall, Harlow u.a.

[11] Kaplan, R.S. and Norton, D.P. (1992), "The balanced scorecard - Measures that drive per-formance", Harvard Business Review, No. 92105.

[12] Knoeri, C., Binder, C.R. and Althaus, H.-J. (2011), "An agent operationalization Approach for Context Specific Agent-Based Modelling", Journal of Artificial Societies and Social Simulation, Vol. 14.

[13] Kua (2016), "A New Integrated Framework for Stakeholder Involvement in Sustainability Poli-cymaking–A Multidisciplinary Approach", Sustainable Development, 24, 5 281-297.

[14] McElroy, B. and Mills, C. (2003), "Managing stakeholders", in Turner, J.R. (Ed.), People in project management, Gower, Aldershot, pp. 757–775.

[15] Mitchell, R.K., Agle, B.R. and Wood, D.J. (1997), "Toward a Theory of Stakeholder Identifica-tion and Salience: Defining the Principle of Who and What Really Counts", Academy of Man-agement Review, Vol. 22 No. 4, pp. 853–886.

[16] Olander, S. (2006), External stakeholder analysis in construction project management, Con-struction management publications, Lund University, Lund.

[17] Olander, S. (2007), "Stakeholder impact analysis in construction project management", Con-struction Management and Economics, Vol. 25 No. 3, pp. 277–287.

[18] Olander, S. and Landin, A. (2005), "Evaluation of stakeholder influence in the implementa-tion of construction projects", International Journal of Project Management, Vol. 23 No. 4, pp. 321–328.

[19] Semaan, N. and Sarkis, S. (2015), "Stakeholder impacted cost contingency model (SICC)", International Journal of Science, Environment and Technology, Vol. 4 No. 3, pp. 690–700.

[20] Yang, J., Shen, G.Q., Ho, M., Drew, D.S. and Xue, X. (2011), "Stakeholder management in