DECISION MAKING ON REVERSE LOGISTICS IN THE GERMAN CONSTRUCTION INDUSTRY

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Abstract- Demolition and construction wastes make about 52 percent of the total generated wastes in Germany and is overall the biggest cause of wastes. Therefore this type of waste has a high impact on the construction industry and the strategy of waste handling belongs to the management of the companies. In Germany different waste management methods such as recycle, reuse, remanufacture and landfill are used. This paper focuses on the decision making about the choice which of the available waste management methods will be used. A questionnaire survey was created to collect necessary data in the German construction industry. Exploratory factor analysis was done to extract key factor influencing the reverse logistic decision. Structural Equation Modelling was then performed to examine the causal relationships of the extracted factors. The four key factors are Management, Investment, Costs and Constraints. The results show that the most important factor are the Constraints. The factor Constraints consist of many items including legislative pressure, site space, availability of landfill, possibility to replace virgin material with wasted components and the level of knowledge of sorting. The factor constraints cannot be influenced by the management or only with a high effort and need of time.Another important finding is the high influence of the factor Management on the factor Cost and factor Investment. As the management of companies makes decisions in terms of budgeting and cost controlling, those decisions influence the amount of costs in a significant way. Additionally all investment decisions are made by the management.

Keywords- Construction Industry, Decision Making, Reverse Logistic, Waste Management

I. INTRODUCTION

Around 10 percent of the German gross domestic product (GDP) is used for construction activities. But nevertheless the competition between the construction companies is high and every company needs to focus on a sustainable management strategy. The construction industry contributes a huge amount of construction and demolition waste (C&D waste). It is important to establish an appropriate reverse logistic strategy to decrease costs and effort. In Germany over 90 percent of the construction waste is recycled but also other methods such as landfill, reuse and remanufacturing are used.

So far no evaluation about the influencing factors on the decision making was done. Therefore the target of the research was to select and examine influencing items and group them into factors. The final target was to create a model with good model fit showing the weight of influence and the relationship between the factors to finally find out which factor has the highest priority on the decision.

II. REVERSE LOGISTIC

Reverse logistics is defined as how the area of business logistics plans, operates, and controls the flow of logistics information, corresponding to the returns of post-sale and post- consumption goods to the productive cycle through reverse distribution channels. Its process benefits in improving economic, ecological, legal, logistical, and corporate image. The process starts when goods, which are in possession of the customers (business or private), are collected. Collections can be stored in different locations, such as, central warehouses or local stores. Once the goods are collected, they are transferred to facilities for sorting and testing.

Four disposition options are listed: 1) recycle, 2) repair, 3 reuse, and 4) remanufacture. Other authors talk about additional disposition options like compost, incinerate, recovery and disposal which are not considered in this analysis. Therefore this study divides reverse logistics into four major types: 1) direct reuse, 2) remanufacturing, 3) recycle, and 4) landfill. These four types of reverse logistics are the most common reverse logistic methods in Germany.

A. Landfill

Landfills are well-engineered modern facilities that are located, designed, operated, and monitored to ensure compliance with regulations. Solid waste landfills must be designed to protect the environment from contaminants, which may be presented in the solid waste stream. Many countries around in the world, however, facing the problem of scarcity of landfills, for example Singapore and Hong Kong.

B. Direct Reuse

Direct reuse is defined as products or components that are traded as they are (without being modified), and can be used a second or multiple times. Within the construction industry, the materials that can be direct reused are plastic containers, electric tools and equipment, furniture, wooden packaging, doors, frames, flooring, ducting, tiles and bricks.

C. Remanufacture

The definition of remanufacturing is an industrial process, in which worn-out products are restored to like-new condition through a series of industrial processes. Usable parts are cleaned, refurbished, and put into inventory. Then the new product is reassembled from the old, and where necessary, new parts to produce a fully equivalent, or sometimes superior, in performance and expected lifetime to the original new product. Remanufacturing is distinctly different from repair operations since products are disassembled completely, and all parts are returned to like-new condition.

In the construction industry, the materials that can be remanufactured are the durable goods with interchangeable parts. An example is sash windows that can be cost-effectively reconditioned by repair and replacement of technical elements, and sometimes upgraded by the addition of, for example, double glazing .

D. Recycle

Recycling processes wastes into new products. It has increasingly been adopted by communities as a method of managing municipal solid waste. It helps lower raw materials and energy requirements, and reduces air and water pollution. In the construction industry, the materials that can be recycled are cardboard and paper, concrete and plastic.

III. ITEMS INFLUENCING REVERSE LOGISTIC DECISIONS

The items below affect the decisions in reverse logistic processes within the construction industry.

1. Availability of Landfill (ALF):
The scarcity of landfills affects the reverse logistic decision.
2. Green Image (GIM):
Can be gained by environmentally friendly business operations and can help to win the favor of the public.
3. Inventory cost (IVC):
Inventory cost is required when storing C&D waste before transferring to the next construction site or destination.
4. Knowledge of Sorting (KLS):
Training laborers in various sorting techniques enhances the sorting effectiveness and, perhaps, reduces labor requirement.
5. Landfill Costs (LFC)
Are the charge or fee to dispose waste to Landfill.
6. Labor cost (LBC):
Labor cost is incurred when companies perform each type of reverse logistics.
7. Legislative Pressure (LPR):
Construction companies have to act according to the principle of sustainability to foster resource preservation and emission avoidance.
8. Limited Project Time (LPT):
Construction projects often have limited time, which might affect the decision to implement the reverse logistics.
9. Limited Site Space (SSP):
Limited site space on the construction site affects the amount of C&D waste stored at the site.
10. Processing cost (PCC):
New knowledge of operation processes lowers the processing cost.
11. Replacement of Virgin Material (RVM):
Reusing waste concrete for backfill materials or coarse aggregate for road construction..
12. Revenue for Material (RFM):
The profit that can be reached by selling the recycled/reused/remanufactured materials and products on the market.
13. Specific Sorting machine (SSM):
Is required in order to effectively sort waste in limited time and also get the possibility to sort special waste.
14. Specific Technology (STG):
Some reverse logistic methods require specific technologies to perform; an example is the making of aggregated concrete.
15. Target Recycling Rate (TRR):
The target recycling rate for member states of European Union (EU) is 70 percent. Nevertheless the management of every company can set a higher target than the by EU given one.
16. Transportation cost (TPC):
Distances from site to site affect the transportation cost and the project budget.

The listed items were used to define a questionnaire to gain data for the analysis. The response was 88 filled questionnaires which represent a response rate of seven percent. There was a high response of persons with a high position, knowledge, experience and the power to influence decision making regarding reverse logistic. More than 65 percent of all participants belong to the Top Management or are department leader as well as project manager. Furthermore 49 percent work in the construction industry for more than 20 years and 31 percent have working experiences of about 10 to 20 years.The main response came from people working in big or medium size companies (70 percent). To make sure the database is reliable and good enough a test has to be done. Therefore the data were transformed into anIBM SPSS file to run the analysis and to create the Structural Equation Model. The used versionwas IBM SPSS Statistics & Amos version 21.Firstly all surveys with missing values were rejected. Secondly the database was tested with the Plot Analysis to check if there are any outliers. The Result was that there are no outliers within the data. Finally the skewness and kurtosiswas tested to make sure that the discrepancy of normal distribution are within the acceptable range.

IV. FACTOR ANALYSIS

For the preparation of the Structural Equation Model it is necessary to do a dimension deduction also called

Factor Analysis. Within this procedure the factors are analyzed with the KMO and Bartlett´s Correlation Matrix. Other settings are the principal axis factoring method,varimax rotation and also the correlation coefficient has to be at least 0.50. That means items have to have at least an affiliation of 0.50 to the recommended group, which is very important to get areliable results.

As viewable in table I the first result are five factors. However LFC does not fit to any of the factor groups, so the items LFC does not affect the decision making process. Due to the described situation the factor LFC was not considered for the further analysis and SEM.

Table I - Factor result with 16 items

		Factors				
	Items	1	2	3	4	5
1	SSM	0.94				
2	STG	0.85				
3	RFM	0.59				
4	LFC					
5	RVM		0.78			
6	SSP		0.63			
7	ALF		0.60			
8	IVC			0.68		
9	LBC			0.60		
10	PCC			0.58		
11	LPR				0.87	
12	TPC				0.63	
13	KLS				0.50	
14	GIM					0.80
15	TRR					0.54
16	LPT					0.50

Doing the Factor Analysis again, without LFC and the same settings, the result shown in Table II are four factor groups. Each factor has more than two items so it can be defined as a factor. As well the correlation coefficient is over 0.50 for each item.

Table II - Factor result with 15 items

		Factor			
	Items	1	2	3	4
1	SSP	0.76			
2	RVM	0.73			
3	ALF	0.70			
4	LPR	0.64			
5	KLS	0.54			
6	SSM		0.89		
7	STG		0.86		
8	RFM		0.55		
9	LBC			0.66	
10	TPC			0.61	
11	PCC			0.57	
12	IVC			0.52	
13	GIM				0.69
14	TRR				0.63
15	LPT				0.60

For the SEM model later and also for easier understanding it is important to rename the factors so that it fits to the related items:

- Factor 1 Constraints
- Factor 2 Investment
- Factor 3 Costs
- Factor 4 Management

1. Constraints Factor

The factor constraints combines physical, social and financial restrictions. It contains all items which effect the construction and also reverse logistic companies in such a way that they either cannot influence this restrictions or need to do an effort and invest money to influence. So in order to run their business and also decide which reverse logistic method has to be used every company have to consider about the constraints. For example the legislative pressure, companies have to follow the requirements and they are not able to change the regulations of reverse logistic. Other components like the specific knowledge of sorting can be influenced but it needs time and effort to improve and train the employees.

2. Investment Factor

In general investment means that money is used with the target to earn more money. In the construction industry the purchase of machinery and other assets (a physical good), to improving future business and also be prepared for the future challenges.

3. Cost Factor

This factor contains all direct costs such as labor cost, inventory cost, transportation cost and processing cost which are related directly to each reverse logistic project for example a demolition of a building.

4. Management Factor

“Management is an individual or a group of individuals that accept responsibilities to run an organization. They plan, organize, direct and control all the essential activities of the organization. Management does not do the work themselves. They motivate others to do the work and coordinate (i.e. bring together) all the work for achieving the objectives of the organization. Management brings together all Six Ms. i.e. Men and Women, Money, Machines, Materials, Methods and Markets. They use these resources for achieving the objectives of the organization such as high sales, maximum profits, business expansion, etc.”.

V. RELIABILITY TEST

To reconfirm the consistency of the data and to confirm the extracted factors a reliability test was done. The most common measure of reliability is the Cronbach´s Alpha. The acceptable value is 0.7.

According to table III it is viewable that all factors reach the target value of 0.7. Therefore the data set and

factors are reliable and a Structural Equation model can be created.

Table III - Result reliability test

Factor	Factor 1 Constraints	Factor 2 Investment	Factor 3Costs	Factor 4 Management
Cronbach´s Alpha	0.83	0.84	0.78	0.70

VI. STRUCTURAL EQUATION MODEL

To show the relationships between the four key factors and whether ascendancies exist a structural equation modelling was done. Components of a general structural equation model are the measurement model and the structural model. Well known fit indices used in measuring model fit are RMSEA, CMIN/DF, and CFI. The value of RMSEA of 0.1 or less, CMIN/DF of less than 2, and CFI of at least 0.9 represent a good model fit.

A. Measurement Model

The measurement model explains the relationships between factors and their items and prescribes latent items, e.g., confirmatory factor analysis. The first measurement model shown in figure 1 is the base model. It considers the main relations between the factors.

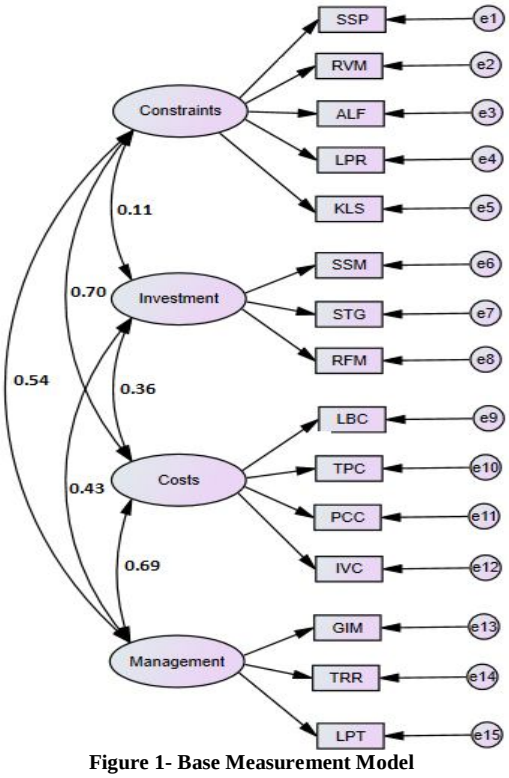


Figure 1- Base Measurement Model

As it is viewable within Table IV themodel fit is not within the range of the acceptable values. Therefore this it is necessary to improve the model fit by using and checking the model indices. Comparing to them and references found in journals and textbooks the relations have to be deleted or inserted. For examplethe arrow from factor Constraints to factor Investment is deleted.After this procedure the model fit was improved.

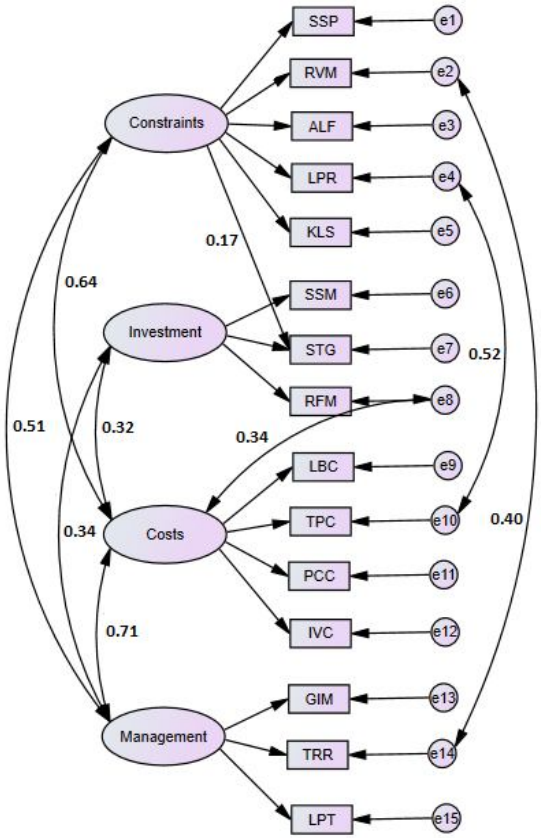


Figure 2- Fit Measurement Model

Table IV - Measurement/Structural Model Data

		CMIN/DF	CFI	RMSEA
Measurement Model	Base	2.267	0.81	0.126
	Fit	1.743	0.90	0.096
Structural Model	Base	2.267	0.82	0.126
	Fit	1.742	0.90	0.096
Accepted Value		< 3	≥ 0.90	≤ 0.100

B. Structural Model

The structural model defines causal relationships between the factors. It prescribes relations between latent items and observed items that are not indicators of latent items.

The Base Model of the Structural Model is shown in figure 3. Only the main relationships are inserted and considered, according to several journals and textbooks. The Base Model shows the relationships between the factors as well as the direction and weight.

Due to the model fit, according to table IV, it is necessary to improve the model. Therefore the same method was used as for the measurement model by considering the model indices. Comparing to that and other references the model could be improved as shown in figure 4.

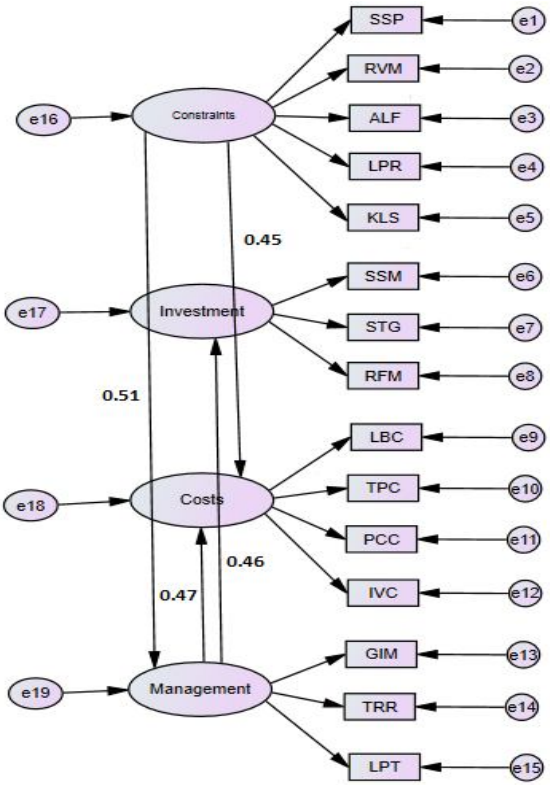


Figure 3- Base Structural Model

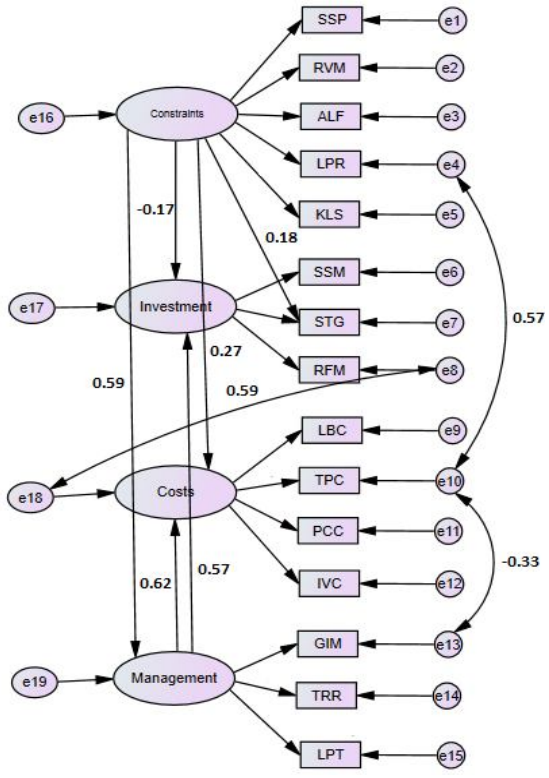


Figure 4- Fit Structural Model

VII. FINDINGS

The main finding out of the structural model is the priority and main importance of the factor Constraints. Constraints influence all other factors but are not influenced by one of the other factors in a significant way.

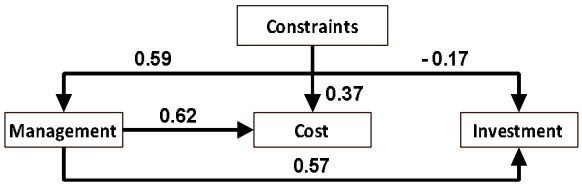


Figure 5- Factor Relations

Not even the management of the company has a high influence on laws and regulations. Site space is often given by the project and cannot be changed or adjusted. The possibilities to replace virgin material are just sometimes given and depend on the construction type. The knowledge of sorting can be influenced by the management as they can set up a training program or influence the recruiting of new employees. This process takes a long time and is connected with a high effort. Therefore the management cannot change the situation immediately but needs to set up a strategy to reach the middle or long term goal of an improvement of the company-owned knowledge of sorting.

Another important finding is the high influence of the factor Management on the factor Cost and factor Investment. As the management of companies makes decisions in terms of budgeting and cost controlling, those decisions influence the amount of costs in a significant way. Additionally all investment decisions are made by the management. Therefore the direct influence of the factor Constraints on the factor Investment has a negative value of -0.17. The negative value is caused of the kind of relationship. Due to higher constraints the decisions for investment activities of the management are restricted. For example if the site space of a construction is limited the management has to decide to invest in special machines which can be used in a space-limited working environment.

There is no interrelation between the factor Cost and the factor Investment. This two factors have a similarity in term of cash reduction and expenses for the companies but in different categories. While costs belong to the variable cost and have a continuous characteristic, investments represent fix costs and occur uniquely.

Germany is a developed country and the structural model would probably show another result if it had be done in a developing country. The costs supposed to have a higher priority in this type of country. To confirm this presumption a detailed analysis of a

developing country as for example Thailand should be done. The detailed comparison between the reverse logistic within the construction industry of a developed and developing country could be another possible further step. If this model should be adapted and used the country status has to be checked first to make sure that the model fits to the given circumstances of the country.

CONCLUSION

Waste management is a cost intensive topic for many companies. Due to increasing importance of sustainability there is a trend to proper and efficient waste handling. It is important to understand the decision making process to see what factors influence the handling of waste and how one factors influences and controls the other factors. Furthermore the research shows how the governmental institutes can influence the waste management.

As this research was done in the developed country Germany,it is important to mention that this model probably will not fit for developing countries. Therefore a further evaluation of decision making within the construction industry of a developing country is suggested and could be a further activity.

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