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## Tracing Hazardous Materials in Registered Records: A Case Study of Demolished and Renovated Buildings in Gothenburg

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# Tracing Hazardous Materials in Registered Records: A Case Study of Demolished and Renovated Buildings in Gothenburg

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**Abstract.** Hazardous materials encountered during building renovation or demolition processes not only result in uncertainty in cost estimation and the lead time but also hampers material recyclability and reuse. Therefore, the paper discusses the possibility of predicting the extent of the hazardous materials, including asbestos, PCB, mercury, and CFC, through data mining techniques based on registered records. Pre-demolition audits contain observation data that can be used as a sample for statistical prediction through careful processing. By developing an innovative approach of merging data from environmental inventories with building registers, the positive ratio of remaining hazardous materials in the Gothenburg building stock can be estimated. The study highlights the challenges of creating a training dataset by completing information from the existing environmental inventory, providing new insight into digital protocol development for enhancing material circularity.

## 1. Introduction

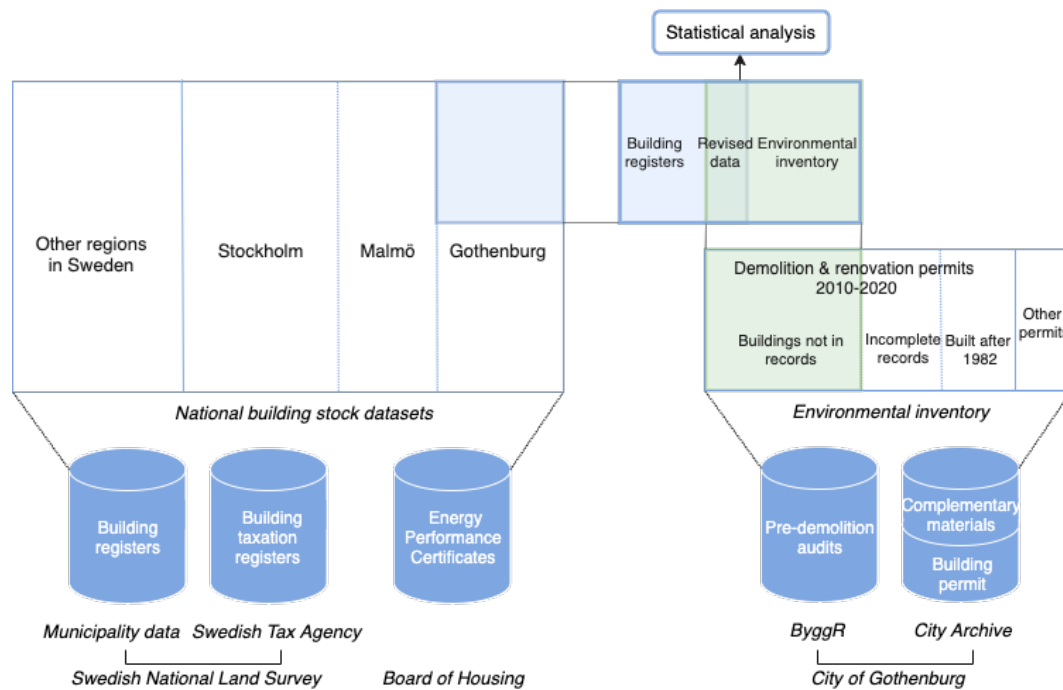
Identifying hazardous materials before demolition and renovation decrease the risk of project delay and unexpected cost for decontamination. Hazardous materials in renovated or demolished buildings endanger human health [1] and require waste disposal and working precautions preparation [2]. Aside from the concern, updating legal requirements for circular construction and extended health criteria of green building certification also demand a higher quality of the existing built environment [3]. Advanced development of data mining and accessibility of governmental open databases make predictive detection of in-situ asbestos and PCB-containing materials in the demolished and renovated projects possible. The study investigates the potential of using existing environmental inventories to characterize the extent of in-situ hazardous materials in the building stock. As the records of demolition audits and national building registers are available for some European countries, the developed method can be adapted to different exposure assessment purposes and multinational comparison studies for devising a standardized and possibly digital pre-demolition protocol.

## 2. Materials and Method

An inference study consisting of several data mining tasks, such as tracking patterns, classification, and association, was performed for the research purpose, illustrated in Figure 1. First of all, pre-demolition audits of buildings demolished and renovated during 2010-2020 were collected from the City Archive of Gothenburg in Sweden and ByggR, a digital database for demolition projects since 2017. Yet, only the subset constructed before 1982 was employed as input data given the year of total ban of asbestos and PCB. After several iterations of the explored data mining process, as shown in Table 1, a set of critical variables including building parameters, environmental investigation level, hazardous substances, and hazardous building components was defined for the training dataset. Using FME Safe Software, Python, and SQL, the collected data were merged with comprehensive datasets from the



Swedish National Land Survey and Board of Housing. A cross-validation workshop was then arranged to validate the data quality and ensure coherent observation between the training dataset and the comprehensive datasets. Furthermore, the representativeness of the regional data subset was evaluated by comparing the data distribution in Gothenburg building stock in terms of building class, construction year, floor area, etc. The correlation between key building parameters and the detection of hazardous materials was investigated through data visualization and statistical operations using Python.



**Figure 1.** Sequence of data mining tasks performed in the inference study.

**Table 1.** Procedure of creating, merging, and cleaning an environmental inventory training dataset.

#	Data operation steps	Description
0	Dataset structure	Assemble common variables across different environmental inventory types. Use “building” as an observation unit and determine the detail level in the training dataset.
1	Data eligibility & completeness	Check eligibility of observation for variables, i.e., year built, inventory executor, and data comprehensiveness. Remove incomplete observations for comparable results.
2	Data leveling & conversion	Cluster type of inventory and experience level of executors. Convert records to the following data types: “Nominal,” “string,” “scale variables,” and “ordinal.”
3	Data extraction & export	Extract data from national building registers by using the real estate name as a key. Harmonize units between “property” and “building” in the comprehensive dataset.
4	Data merging & formatting	Establish general compliance of formats and measurement of the variables of interest, then merge the training dataset through aggregating multiple records.
5	Data revision & manipulation	Check consistency between variables and harmonize deviation by creating revised data. Fill in missing data with proxy and label NA if not found in any dataset.

### 3. Findings

The screening of the pre-demolition audits resulted in 402 valid observations at four levels of investigations, described in Table 2. Leveling was based on data completeness in descending order; namely, level 1 includes the most details while level 4 is the least. Detailed investigations, such as consultancy reports and protocol, accounted for 70% of the dataset with high data reliability and completeness. The percentage of missing data lower than 20% differs concerning hazardous substances and inventories. Protocols and reports had high coverage of hazardous substances than control plans and demolition plans as industry-standard hazardous waste lists were followed. On the contrary, a template

of the demolition control plan was developed for simple buildings or single-family houses. The average area for the observation group was small, and it only contained general detection information. A high amount of missing data and invalid observations were reported as the information about the extent of the investigation was lacking. These simple investigations were conducted mainly by contractors or private persons for small-scale renovation or demolition projects. In contrast, detailed investigations were executed primarily by experts for complicated or contaminated buildings. No significant difference was found between the average year built and the investigation type in the study.

Concerning hazardous substances, asbestos, PCB and mercury were thoroughly investigated in reports and protocols with a low number of missing data and a high positive ratio. In comparison to this, the presence of CFC was better assessed in the protocol and control plan. The results variation may be explained by the difficulty of distinguishing hazardous building components and the different years of usage ban. For mercury and CFC-containing materials, they can be identified visually through labels or installation year, while evaluating the presence of asbestos and PCB requires sampling and lab analysis. Cross-evaluating the positive detection ratio and the amount of missing data can offer an understanding of the potential improvement of pre-demolition audits.

**Table 2.** Evaluation of the environmental investigations for the hazardous substances in the Gothenburg building stock subset.

Type	Level 1 (Report)		Level 2 (Protocol)		Level 3 (Control plan)		Level 4 (Demolition plan)	
Number	195 (50%)		88 (20%)		42 (10%)		77 (20%)	
Average year built	1958		1952		1951		1952	
Average area (m <sup>2</sup> )	4202		1066		967		1973	
Substance	Positive ratio <sup>a</sup>	NA	Positive ratio <sup>a</sup>	NA	Positive ratio <sup>a</sup>	NA	Positive ratio <sup>a</sup>	NA
Asbestos	<b>0.84</b>	<b>6%</b>	<b>0.51</b>	<b>9%</b>	0.47	<b>14%</b>	0.70	27%
PCB	<b>0.63</b>	<b>8%</b>	0.49	<b>10%</b>	0.19	26%	0.51	52%
CFC	0.79	34%	<b>0.60</b>	<b>12%</b>	<b>0.62</b>	<b>19%</b>	0.50	56%
Mercury	<b>0.99</b>	<b>11%</b>	<b>0.72</b>	<b>3%</b>	0.55	26%	0.76	35%

<sup>a</sup> Positive ratio = Number of Positives / (Total number of Observation – Number of NA)

#### 4. Conclusions

The study proves the potential of leveraging the extant registered records as data input for tracing hazardous materials in Gothenburg building stock. By connecting environmental inventories from pre-demolition audits and the national building registers, we will hopefully estimate the extent of the remaining hazardous materials in the building stock. The challenges of assembling various environmental inventories and the importance of high-quality data were underlined as a prerequisite for conducting comprehensive and reliable analysis. Difficulty in harmonizing diverse data granularity and missing data was encountered when developing consistent criteria for observation; thus, necessary revisions and iteration were made. The study contributes to circular construction regarding developing a methodology for identifying in-situ hazardous materials within the framework of EU C&D waste management. Constructing the training dataset set a precedent case for utilizing environmental inventory data and can be regarded as a pilot work for devising digital pre-demolition protocol in the future.

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