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## МИНОБРНАУКИ РОССИИ

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«Юго-Западный государственный университет»  
(ЮЗГУ)

Кафедра иностранных языков



### СМЫСЛОВОЙ АНАЛИЗ ИНОЯЗЫЧНЫХ ТЕКСТОВ СТРОИТЕЛЬНОЙ НАПРАВЛЕННОСТИ

Методические рекомендации для самостоятельной работы  
по дисциплине «Профессиональный иностранный язык»  
для обучающихся на факультете строительства и архитектуры  
по направлениям подготовки: 07.04.01, 08.04.01, 13.04.01

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**Смысловой анализ иноязычных текстов строительной направленности** : методические рекомендации для самостоятельной работы по дисциплине «Профессиональный иностранный язык» для обучающихся на факультете строительства и архитектуры по направлениям подготовки: 07.04.01, 08.04.01, 13.04.01 / Юго-Зап. гос. ун-т; сост.: В.В. Махова. – Курск, 2023. – 47 с.:– Библиогр.: с. 46.

Методические рекомендации «Смысловой анализ иноязычных текстов строительной направленности» содержат комплекс заданий и упражнений, способствующий формированию коммуникативных и языковых компетенций, а также компетенций, способствующих активному вхождению обучающихся в сферу их профессиональной деятельности. Методические рекомендации соответствуют требованиям ФГОС ВО.

Предназначены обучающимся по следующим направлениям подготовки: 07.04.01, 08.04.01, 13.04.01 для самостоятельной работы с целью освоения дисциплины «Профессиональный иностранный язык».

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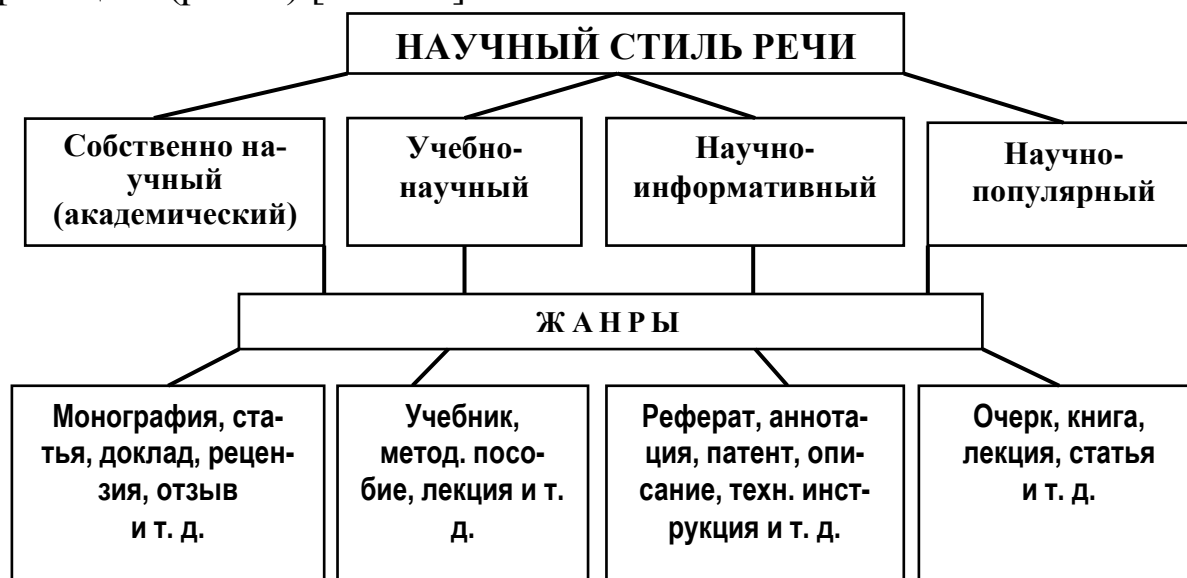
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# І. НАУЧНЫЙ ТЕКСТ

## 1. Особенности научного текста и его сущностные характеристики

**Текст** – это произведение речевого процесса, обладающее завершенностью, представленное в виде письменного документа, состоящее из названия и ряда особых единиц (сверхфразовых единств), объединенных разными типами лексической, грамматической, логической, стилистической связи, имеющее определенную направленность, прагматическую установку [12].

Научный текст обеспечивает коммуникацию (общение) между специалистами/учеными в той или иной научной сфере. Исследователи по-разному подходят к **классификации научных текстов**. Так, Н.Д. Чебурашкин считает, что научно-техническую информацию можно разделить на патентную литературу; периодику; издания для научно-технического обмена [17: с. 77]. И.Г. Проскурякова предлагает следующую функционально-стилевую классификацию (рис. 1) [13: с. 5]:



**Рис. 1** Функционально-стилевая классификация научных текстов (по И.Г. Проскуряковой)

Любой текст, в том числе и научный, обладает рядом характеристик (категорий). Одной из наиболее существенных категорий текста является **категория связанности**. В составе предложения нет системных грамматических указаний, как перейти к следующему предложению, последовательность предложения задумана говорящим для того, чтобы в речи появился смысл, а реализация

грамматических правил в предложении обеспечивается автоматизмом памяти [8]. Таким образом, закономерность смыслового структурирования текста является не языковой, а психологической, поэтому грамматика текста не может объяснить смысловую связности текста.

Другая характеристика текста – **смысловая целостность**. Значение есть только одна из зон того смысла, которое приобретает слово в контексте [3: с. 305]. Выявляют 1) материальную форму знака, 2) предметное значение, 3) смысловое значение, 4) оценочное отношение, 5) переживание. Прохождение от пятого к первому уровню – есть опредмечивание опыта, его объективация. Обратный путь – субъективация, путь понимания. Связи между отдельными частями целого текста всегда слабее, нежели внутри них, и обеспечиваются, как правило, иными средствами – механизмами смысловой связи [2: с. 67], связность обуславливается линейностью текста, а целостность – введением текста в соответствующие парадигматические отношения [11: с. 11], целостность – это потенциальное проекционное состояние строевых и нестроевых элементов языка/речи [14: с. 30].

Таким образом, связность и смысловая целостность являются сущностными характеристиками текста. Связность – условие целостности текста. Связность доступна восприятию, постижение целостности требует осмысления. Отсутствие любой из этих характеристик влечет разрушение текста.

Важной характеристикой научного текста является его **композиционная структура**. И.Г. Проскуракова указывает, что «в каждом тексте должны присутствовать: посылка (тезис)→аргументы→вывод» [13: с. 22] и обращает внимание на основы компрессии научного текста (виды компрессии: реферат, аннотация, тезисы, конспект), ключевые слова, правила построения – сегментацию [13: с. 74, с. 150].

А.С. Герд выделяет следующие компоненты структуры научного текста: макроструктура (композиция, типы и расположение разделов, глав, параграфов, абзацев, графов); лексика (общезыковая, общенаучная, узкотерминологическая); морфологические и словообразовательные средства; синтаксис; семантика [5: с. 87].

Одной из наиболее важных характеристик научного текста является **смысловая структура научного текста**. И.Г. Проскурякова, рассматривая научные тексты, выделяет: текст-характеристику, текст-определение, текст-классификацию, текст-повествование, рассуждение и доказательство.

Структура текста может рассматриваться в плане содержания и в плане выражения. Структурированность текста в плане содержания проявляется через взаимные связи и порядок расположения его смысловых единиц; структурирование текста в плане выражения проявляется через взаимные связи и порядок расположения компонентов его формы [1: с. 3].

Научной речи характерны *эксплицитность, логизированность, объективизированный характер изложения, высокая стандартизованность, абстрактность, отвлеченно-обобщенный характер, лаконичность* [1: с. 15;13; 6]. Для научного текста также характерна свернутость логических отношений, которую называют *информативно-логической плотностью*[13].

Термин «**информация**» предполагает его использование в двух значениях: 1) как всякое сообщение, оформленное как словосочетание номинативного характера (предложение, сочетание предложений, текст в целом); 2) в работах по теории коммуникации лишь при получении новых сведений о предметах, явлениях, отношениях, событиях объективной действительности»; таким образом, в научно-теоретическом плане не всякое сообщение несет в себе информацию. Для проведения смыслового анализа научного текста категория информативности особенно важна, причем особое значение имеет лексический состав научного текста, который характеризуется использованием терминов.

**Термин** – это языковой знак, выражающий специальное научное понятие и отражающий место этого понятия в соответствующей системе научных понятий, системе знаний [12: с. 13]. Основные **признаки термина**: 1) *точность*; 2) *однозначность*; 3) *отсутствие эмоциональности*; 4) *мотивированность* (термин – вторичное наименование); 5) *номинативность* – соотнесение термина с понятием; 6) *дефинитивность* – значение термина, сформулированное в виде логического определения; 7) *системность* –

свойство занимать определенное место в системе терминов 8) *систематичность* – свойство отражения системности 8].

Таким образом, характеристики научного текста – многоаспектны. Целостность и связность, эксплицитность, структурированность, стандартизированность и лаконичность – неотъемлемые черты любого научного текста; важнейшей характеристикой научного текста является информативность, важнейшим компонентом – термин, которому свойственны системность и понятийность.

## **2. Способы смысловой обработки и структурирования информации иноязычного научного текста**

В сферу деятельности современных специалистов в условиях двуязычной профессиональной коммуникации попадают иноязычные научные тексты, поэтому нередко возникают проблемы их переводимости.

Перевод является специфическим видом речевой деятельности и включает в себя: 1) восприятие исходного текста (ИТ); 2) понимание ИТ на уровне поверхностных структур (связь слов, высказываний); 3) сопоставление с имеющимися знаниями; 4) глубинное понимание (смысл); 5) адекватную передачу полученной информации на ПЯ. Переводческая компетенция включает в себя адекватное выполнение вышеназванных операций с использованием кодов ИЯ и ПЯ. Смысл текста – главный объект внимания при выполнении перевода. Смысл текста не поддается экспликации (открытому, явному словесному выражению семантических компонентов) – выявлению лингвистическими методами, так как он возникает не только на основе функционирования языковых единиц и включает в себе такие подсмыслы, которые лежат в сфере ведения других дисциплин [7: с. 48]. Для понимания исходного письменного текста необходимы **просмотровое, ознакомительное и изучающее чтение**.

**Моделирование** – это научный прием, состоящий в схематичном воспроизведении объекта. Под **моделью текста** понимается образец языковой единицы, показывающий последовательное расположение составляющих ее частей, которое связано с **анали-**

**тико-синтетической обработкой информации** – смысловым анализом текста, вычленением единиц информации, оценкой этой информации и ее синтезом в очень сжатой форме [12: с.]. **Синтез**–объединение элементов в более глубокие единицы, а **смысловый анализ** – обязательная операция при восприятии исходного текста, цель которой – определение смысла и выделение инвариантной информации [12]. **Модель научного текста** – отражение ядерных структурно-смысловых внутритекстовых связей, фиксированных в схеме: темы, коммуникативной задачи текста, данной и новой информации, текстообразующих функций предложения, способов развития информации текста.

Таким образом, моделирование научного текста позволяет выявлять наиболее общие характеристики, прогнозировать возможные изменения, происходящие в тексте в силу определенных обстоятельств. При моделировании определяются как эксплицитные, так и имплицитные компоненты смысловой структуры текста, которые выражены не только собственно языковыми средствами, но и при помощи подтекста, контекста и фонового окружения самого текста с целью постижения авторских намерений.

Выделяют следующие задачи обработки структуры научного текста: анализ макроструктуры текста; моделирование семантики, построение по текстам логико-понятийных систем и терминосистем; разработка графического представления данных; моделирование отдельных видов грамматических отношений; мотивационно-целевой анализ текста и предметно-содержательный анализ (с помощью каких языковых средств), при этом, смысловая интерпретация текста (не пересказ) включает макроструктуру текста и микроструктуру текста. [12: с. 30]. Синтезирующий (интегрирующий) метод анализа текста состоит в том, что все его части рассматриваются, как изолировано, так и во взаимосвязи [6: с. 124].

**Композиционная структура** научного текста – последовательность содержательных элементов текста (название; главы, части; подглавы, параграфы; абзацы). Они являются формальной структурой текста. Вычленяя композиционную структуру текста, необходимо учитывать его **смысловую структуру**, которая обычно рассматривается в связи с задачей компрессии текста. Анализ текста с целью его свертки требует вычленения смысловых единиц,

не всегда соответствующих предложению, абзацу или всему тексту [6].

Таким образом, при построении модели научного текста нужно учитывать содержательную, композиционную и смысловую структуры.

### **3. Смысловой анализ иноязычного текста**

Понимание текста происходит путем анализа и выявления семантических признаков элементов модели, соответствующих контексту (анализ) и заполнения ролей глубинной смысловой модели (с учетом отношений между элементами) (синтез).

Умения смыслового анализа и моделирования можно трактовать как средство, направленное на: зрительное восприятие читаемого; осмысление и понимание значения читаемого; извлечение и активную переработку информации из письменного текста; декодирование смысла, заложенного автором в тексте; совершенствование личности читателя посредством развития его когнитивного мышления и речи.

Таким образом, происходит формирование определенных стратегий восприятия текста, которые включают в себя идентификацию контекста в общем плане, а также связанных с этим контекстом знаний, что приводит к активизации соответствующей ментальной схемы.

Целью смыслового анализа является научение оперированию получаемой информацией, которое опирается на когнитивные механизмы мышления и памяти и способствует пониманию смысла текста.

Для лучшего понимания в качестве примера приведем вариант осуществления смыслового анализа и моделирования научного текста, согласно разработанной С.Э. Харзеевой процедуре, на русском языке [16: с. 37] (рис. 1):

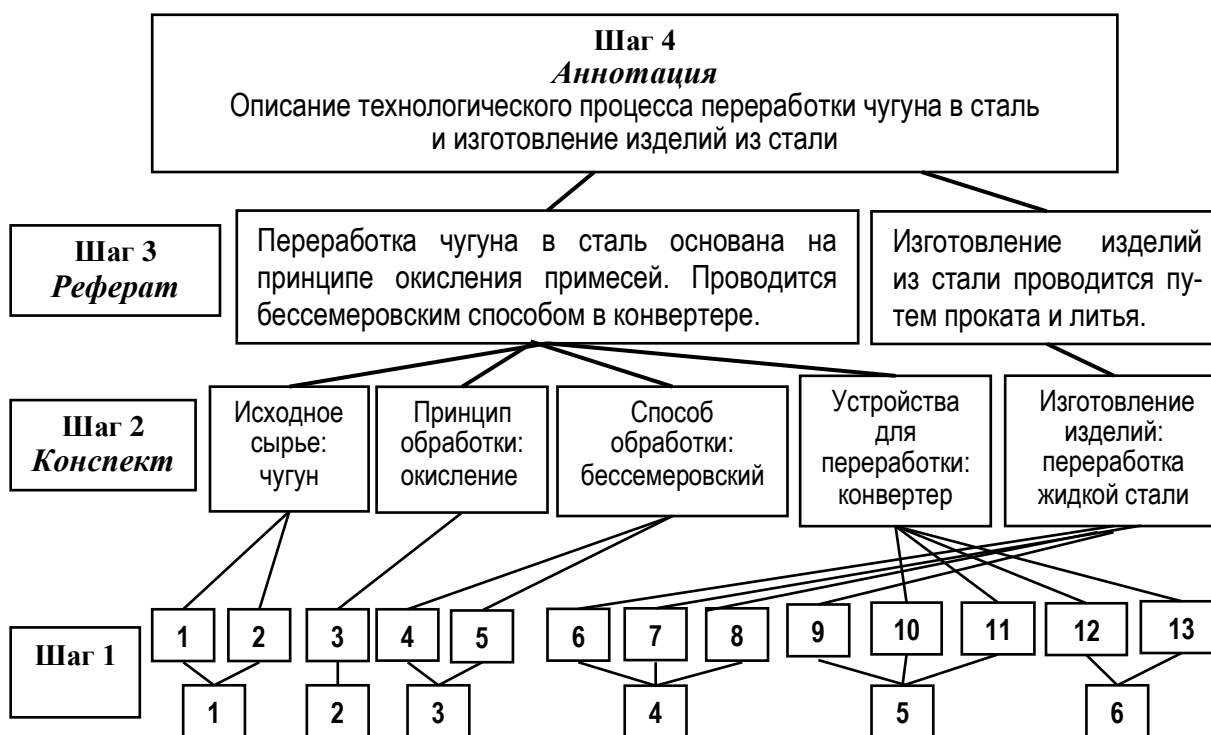
#### ***Производство стали***

*Производство стали основывается преимущественно на чугуне, получаемом из руды в доменных печах. При этом содержание углерода в чугуне снижается путем окисления от 3,5% до 1,3-0,02% в зависимости от требуемого сорта стали.*



Методы получения стали используют высокие температуры и дают сталь в жидком состоянии, причем находящиеся также в жидком состоянии шлаки легко отделяются. Жидкая сталь заливается в кокиль для получения чушек, которые затем прокатываются на прокатных станах в заготовки, рельсы, балки, прутковое железо, трубы или в листовую сталь, либо в сталелитейных цехах разливается в сухие песочные формы для получения стального литья.

По введенному в 1855 году Бессемером бессемеровскому способу превращение чугуна в сталь происходит в опрокидывающемся сосуде (конвертере), снабженном огнеупорной футеровкой, содержащей кремниевую кислоту, в который чугун заливается в жидком состоянии. Через конвертер снизу продувается воздух или обогащенная кислородом воздушная смесь, которая проходит через ванну с чугуном, что вызывает быстрое выгорание углерода и спутников железа.



Предложения исходного текста

**Рис. 1** Реализация процедуры смыслового анализа и моделирования текста (по С.Э. Харзеевой)

Вышеназванный метод был адаптирован для применения к иноязычным научным текстам с учетом языковых различий [10]. Моделирование смыслового предпереводческого анализа представлено в таблице 1.

Таблица 1

### Модель смыслового информационного анализа текста

Виды действий	Этапы моделирования
Аналитические действия	1) выделение исходных предложений из текста
	2) выявление глагольных и отглагольных форм в исходных предложениях
	3) восстановление глаголов-сказуемых путем трансформации выявленных отглагольных форм
	4) построение простых предложений с использованием глаголов-сказуемых
Синтетические действия	5) соотнесение полученных простых предложений с элементами когнитивной схемы и соответствующее переструктурирование текста

Учитывая способы и формы сохранения и репрезентации информации в когнитивных ментальных структурах человека (о чем говорилось ранее), могут разрабатываться различные варианты когнитивных схем. Некоторые варианты когнитивных схем, которые могут служить опорой при реализации смыслового предпереводческого анализа в качестве модели, приведены в таблице 2 [10].

Таблица 2

### Варианты когнитивных схем

<p><b>Схема «Научное исследование»</b>  <b>“Scientific Research”</b></p> <p>Описание проблемы  (постановка задачи)</p> <p>Факты  Гипотезы  Аргументы  Выводы  Заключение</p>	<p><b>Схема «Естественнонаучное явление»</b>  <b>“Natural-Science Phenomenon”</b></p> <p>Агенты  Действие (феноменологическое описание)  Инструмент (механизм действия)  Условия  Результат</p>
<p><b>Схема «Технология»</b>  <b>“Technology”</b></p> <p>Цель  Средства  Объект обработки:  материалы  исходные продукты  конечные продукты  Способ обработки  Условия обработки  Результат: эффективность  широта применения  Персонал и организация работы</p>	<p><b>Схема «Биографическое описание личности ученого»</b>  <b>“Biographic Description”</b></p> <p>Область деятельности  Жизненный путь  Хронология жизненных событий  Личная жизнь, семья  Наиболее известные произведения (работы)  Внешность  Личностные качества  Политические убеждения  Критика, полемика</p>
<p><b>Схема «Развитие техники»</b>  <b>“Technological Expansion”</b></p> <p>Научная область  Этапы развития: научные идеи/события</p> <p>Время  Место  Автор  Технические характеристики  Теоретическая значимость  Практическая значимость</p>	<p><b>Схема «Классификация»</b>  <b>“Classification”</b></p> <p>Предметная область  Классифицируемое множество объектов  Классификационные признаки (критерии классификации)  Типы классификационных объектов</p> <p><b>Схема «Описание объекта»</b>  <b>“Description of an Object”</b></p> <p>Объект  Состав  Структура  Свойства/ характеристики  Получение  Применение</p>

Использование когнитивных схем, на наш взгляд, являются самым важным элементом процедуры, поскольку «вынуждает» использовать накопленный когнитивный опыт, способствует актуализации и расширению фоновых знаний и ведет к адекватному извлечению информации из иноязычного научного текста, а также переносу знаний из одной области в другую.

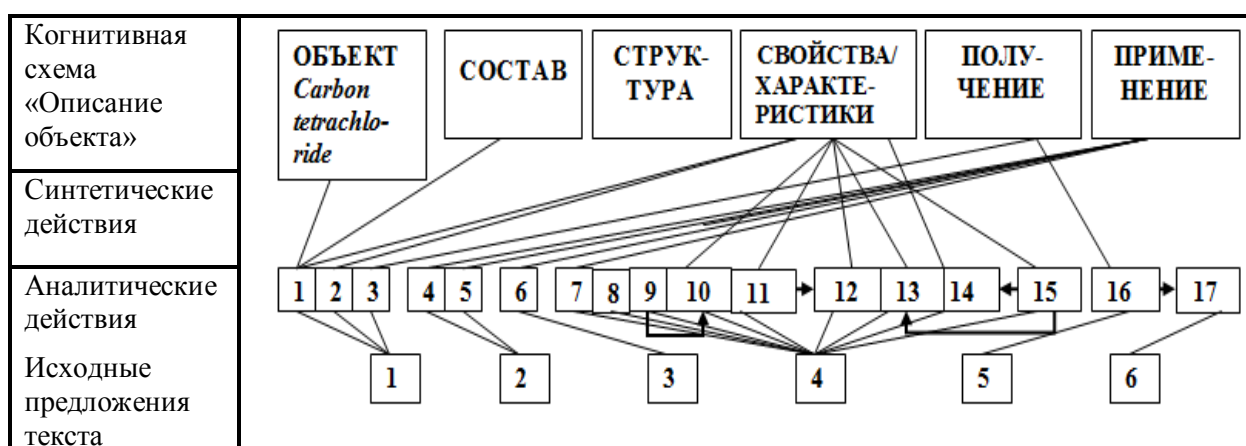
Модель процедуры смыслового предпереводческого анализа приведена ниже:

### Модель смыслового анализа текста

#### Текст<sup>1</sup>

Carbon tetrachloride is a colorless and inflammable liquid that can be produced by combining carbon disulfide and chlorine. This compound is widely used in industry today because of its effectiveness as a solvent as well as its use in the production of propellants. Despite its widespread use in industry, carbon tetrachloride has been banned for home use. In the past, carbon tetrachloride was a common ingredient in cleaning compounds that were used throughout the home, but it was found to be dangerous: when heated, it changes into a poisonous gas that can cause severe illness and even death if it is inhaled. Because of this dangerous characteristic, the United States revoked permission for the home use of carbon tetrachloride in 1970. The United States has taken similar action with various other chemical compounds.

В схематичном виде модель текста с использованием когнитивной схемы может быть представлена следующим образом (Рис. 8):



**Рис. 8. Модель текста “Carbon tetrachloride”, представленная согласно схеме «Описание объекта»**

<sup>1</sup> Источник: Phillips D. Longman Complete Course for the TOEFL Test. Longman, 2001. – 684 p.: p. 344

То есть выполняются следующие действия:

**1 – выявление исходных предложений из текста;**

**2 – выявление глагольных и отглагольных форм в исходных предложениях;**

№ пред-лож.	3. Восстан. гл.-сказ. (трансформ. выявл. отглагол. форм)	4. Построение простых предложений с использованием глаголов-сказуемых (восстановление подлежащих, выраженных местоимениями)
1	is	1. Carbon tetrachloride is a colorless liquid. 2. Carbon tetrachloride is an inflammable liquid.
	can be produced	3. Carbon tetrachloride (that) can be produced by combining carbon disulfide and chlorine.
2	is used	4. This compound (carbon tetrachloride) is widely used in industry today as a solvent. 5. This compound (carbon tetrachloride) is widely used in industry today in the production of propellants.
	has been banned	6. Carbon tetrachloride has been banned for home use.
4	was	7. Carbon tetrachloride was a common ingredient in cleaning compounds.
	were used	8. Cleaning compounds (that) were used throughout the home.
	was found	9. It was found.→
	is	10. →Carbon tetrachloride is dangerous.
	is heated changes	11. When carbon tetrachloride is heated. _____→ 12. Carbon tetrachloride (it) changes into a poisonous gas.
	can cause is inhaled	13. A poisonous gas (that) can cause severe illness. 14. A poisonous gas (that) can cause even death. }← 15. If a poisonous gas (it) is inhaled. _____→
5	revoked	16. The United States revoked permission for the home use of carbon tetrachloride in 1970.
6	has taken	17. The United States has taken similar action with various other chemical compounds.

**5 – соотнесение полученных простых предложений с элементами когнитивной «схемы» и соответствующее переструктурирование текста**

Таким образом, полная модель текста при реализации процедуры смыслового анализа принимает следующий вид (Таблица 3):

Таблица 3

**Полная модель текста при реализации процедуры  
смыслового анализа**

<b>Схема «Описание объекта»</b>
<b>Объект</b> <i>Carbon tetrachloride</i>
<b>Состав</b> -----
<b>Структура</b> -----
<b>Свойства/ характеристики</b>
<p>1. <i>Carbon tetrachloride is a colorless liquid.</i>  2. <i>Carbon tetrachloride is an inflammable liquid.</i>  9. <i>It was found.</i> → 10. <i>Carbon tetrachloride is dangerous.</i>  11. <i>When carbon tetrachloride is heated</i> → 12. <i>Carbon tetrachloride changes into a poisonous gas.</i></p> <p>15. <i>If a poisonous gas is inhaled</i> ↗ 13. <i>A poisonous gas can cause severe illness.</i>  ↘ 14. <i>A poisonous gas can cause even death.</i></p>
<b>Получение</b>
3. <i>Carbon tetrachloride can be produced by combining carbon disulfide and chlorine.</i>
<b>Применение</b>
<p>4. <i>This compound (carbon tetrachloride) is widely used in industry today as a solvent.</i>  5. <i>This compound (carbon tetrachloride) is widely used in the production of propellants.</i>  6. <i>Carbon tetrachloride has been banned for home use.</i>  7. <i>Carbon tetrachloride was a common ingredient in cleaning compounds.</i>  8. <i>Cleaning compounds (that) were used throughout the home.</i>  16. <i>The United States revoked permission for the home use of carbon tetrachloride in 1970.</i>  17. <i>The United States has taken similar action with various other chemical compounds.</i></p>

Естественно, модель вышеприведенного текста может быть записана и в более сжатом виде (Таблица 4):

Таким образом, при выполнении смыслового анализа с целью адекватного извлечения информации и последующего перевода, мы объединяем «психологическое» и «лингвистическое», а это важно для осмысленного восприятия текста. Постигая структуру иноязычного текста с использованием разработанной процедуры и когнитивных схем, работающие с текстом переходят от уровня предложения на уровень дискурса и актуализации фоновых знаний; выполняющие смысловой анализ текста проходят через сле-

дующие уровни восприятия текста: материальная форма знака, предметное значение, смысловое значение, оценочное отношение, переживание, что свидетельствует о субъективации, то есть понимании смысла сообщаемого. Контекст и когнитивные схемы помогают воспринимать экстралингвистическую информацию, которая способствует актуализации полученных ранее фоновых знаний, их расширению и формированию когнитивных ментальных схем. Структурирование информации способствует надежному адекватному размещению полученной информации в когнитивных ментальных структурах читающего.

Таблица 4

**Модель текста «Carbon tetrachloride»  
(схема «Описание объекта»)**

<b>Элемент схемы</b>	<b>Информация, извлеченная из текста</b>
<b>Объект</b>	<i>Carbon tetrachloride</i>
<b>Состав</b>	–
<b>Структура</b>	–
<b>Свойства/ характеристики</b>	<i>inflammable liquid dangerous when heated, it changes into a poisonous gas, which, if inhaled, causes severe illness, even death</i>
<b>Получение</b>	<i>combining carbon disulfide and chlorine</i>
<b>Применение</b>	<i>is widely used in industry as a solvent is widely used in the production of propellants has been banned for home use was a common ingredient in cleaning compounds</i>

## II. ТЕКСТЫ ДЛЯ СМЫСЛОВОГО АНАЛИЗА

### ТЕХТ 1 [18]

Modernism first emerged in the early twentieth century, and by the 1920s, the prominent figures of the movement – Le Corbusier, Walter Gropius, and Ludwig Mies van der Rohe – had established their reputations. However, it was not until after the Second World War that it gained mass popularity, after modernist planning was implemented as a solution to the previous failure of architecture and design to meet basic

social needs. During the 1930s as much as 15% of the urban populations were living in poverty, and slum clearance was one of the many social problems of this decade.[1] Modernist planning was a popular idea, and used as a solution to these problems. But the movement could not adequately comprehend and cater for the social dynamics of family and community, and a result, many modernist buildings were pulled down in the seventies. With reference to key architectural studies, this essay discusses the principles of modernism, how modernist architects initially worked to solve design problems through the creation of urban utopias, and why the ambitious modernist dream ultimately failed.

Students at the Bauhaus school of design were taught purity of form and to design for a better world by Walter Gropius. The phrase ‘form follows function’ is often used when discussing the principles of modernism. It asserts that forms should be simplified – architectural designs should bear no more ornament than is necessary to function. Modernists believe that ornament should follow the structure and purpose of the building. Family life and social interaction was at the centre of the modernist dream for a planned environment. “The vision was for trouble free areas by mixing blocks with terraces to create squares, zoning services and amenities, all interlinked by roads”. [2] The modernists planned for zoned areas where residential and commercial amenities were distinct and separate. In his introduction to *Modernism in Design*, Paul Greenhalgh outlined key features in modernist design including function, progress, anti-historicism and social morality.[3] These principles can be found in many of the key realisations of the modernist dream – Le Corbusier’s famous Villa Savoye in Poissy, France is a prime example. It shows no reference to historic architectural design; the pioneering plan was a progressive leap for the late 1920s. The form clearly follows the intended functions of the residential building, bearing no unnecessary ornament, and the open space surrounding the structure as well as the open plan interior lends itself to the ideals of social living and communication. The modernist ideals were not applied to social housing until 1937, when Maxwell Fry’s Kensal House in London applied the principles of the movement to a social housing scheme. It was a success and is still popular with its residents today. It then became the prototype for other social housing projects to follow the example of modern living.



Many projects of the modernist era were initially successful, and the public came to associate this strong aesthetic with prosperity and progress. In the post war era, the ambitions of the modernists and their “strong sense of social responsibility in that architecture should raise the living conditions of the masses.”[4] seemed so progressive and promising that it was understandable the Architectural Review should herald the movement as the style of the century.

One successful project by the architect Ralph Eskrine was the Byker Housing project in Newcastle, which began in the 1960s. Historically, Byker began as a village, but by the late 19th century the dominant type of housing in the working class area was the Tyneside flat. Conditions were poor, and occupants of the area generally suffered from overcrowding, poor sanitation and poverty. Despite the less than desirable situation, Byker was noted for its character, and the strength of neighbourly relationships. The design team were keen to retain this sense of community, and as such, “Byker was one of the first major attempts in Britain to create a dialogue between community and architecture.”[5]

The public housing development combines a perimeter type wall of multi storey flats, low rise housing and public spaces and play areas. The wall makes use of a south facing aspect to utilise light and views across the city and of the River Tyne. 20 percent of the accommodation is housed in the wall, but the remaining majority was contained in the low rise houses within.[6] The project took a modern approach to living, yet mixed it with a consideration for those who would reside there, a lack of which has been a criticism of many modernist developments. Eskrine adopted a more humane approach to the modernist principles, yet still established clean lines, function, progress, and above all social morality. He worked his plan around Victorian elements of the area such as churches, and some of the original cobblestones and parts of the demolished Newcastle City Hall, were incorporated into the public areas. Perhaps the integration of local history in this manner, which goes against one of the principles of modernism established by the pioneering architects of the movement, and outlined by Greenhalgh, was a contributing factor to the widely agreed attitude that this project was a success. Although it was expressed that “some missed the streets as places of community and gathering, and as arenas or personal expres-

sion.”[7] , The majorities were happy to reside in the new development, thanks to the social continuity and comfortable varied environment provided. This issue was also a concern of Jane Jacobs, author of *The Life and Death of Great American Cities*. In her book, Jacobs accused Le Corbusier, one of the pioneers of the movement, of an inhumane planning process that did not properly consider those who were to live in the planned developments. She claimed the modernist aesthetic to be dull, and her writing promoted the street, in particular the pavement, as a place where a community can meet, socialise, and control their own privacy. [8]

However not all modernist social housing projects were as successful: many were demolished from the 1970s due to large-scale failure. The ultimate example of the failure of the modernist utopia is the now infamous Pruitt Igoe urban housing development in St. Louis, Missouri, completed in 1955. The development was planned according to the modernist principles of Le Corbusier, and comprised of 33 11 storey high rise blocks made up of small individual apartments. There were communal areas including large corridors, outdoor spaces around the blocks, and communal rooms for activities such as laundry, intended to increase the social interaction amongst the community.

However by the late 1960s, “the project's recreational galleries and skip-stop elevators, once heralded as architectural innovations, had become nuisances and danger zones. Large numbers of vacancies indicated that even poor people preferred to live anywhere but Pruitt-Igoe.”[9] Poverty, crime and segregation of the community were major problems for the residents of the development. It was suggested that the modernist style was to blame for these social problems, and comparisons with the adjacent Carr Village can be used as an example to back this up. The village was made up of low rise dwellings, with a similar demographic make-up to Pruitt Igoe, yet remained both fully occupied and trouble free throughout the period from construction to demolition of it's neighbouring development. [10]

Much publicity developed in 1972, when the first of the buildings was demolished on March 16th. The day was declared by the architect Charles Jencks to be the day on which modern architecture died in his book *The Language of Post Modern Architecture*.

Le Corbusier noted the positive force technology had played in people's lives with revolutionary inventions such as the car and the telephone, and declared the house should be "a machine for living in". They utilised glass, steel and concrete in their designs, which allowed them the opportunity to create buildings of radical design, such as the skyscraper, which would not have been plausible were it not for these materials. Buildings like these have no doubt, even today, redefined the urban landscape. He and the other modernist architects believed that a for a home to provide its function it should have the purity of form of a well-designed machine.[11] This principle may work well enough when applied to a commercial building, but which family can honestly say they operate like a machine, like clockwork? Some modernist apartment blocks even went so far as to dictate and include the furniture and blinds, to keep a pure aesthetic throughout the whole building. Removing home comforts from the domestic interior may well encourage purity within design, but it does little to encourage the creation of a 'home' rather than a house.

The pioneers of the movement held a firm belief that in creating a better architecture, a better world would ultimately follow.[12] We could say they were a little arrogant and ambitious in hoping to change the world with their design principles. There is no doubt that a new architecture would improve towns and the living situation of many, however to assume that it could improve the world as a whole is completely nonsensical. What about problems of economy and political debate? Perhaps the reason the modernist utopia is so often cited as a failure is because of its unrealistic ambitions. There is no doubt that modernism, to an extent, solved some design problems by keeping abreast of technology. Lubetkin's HighPoint One flats in London are still as desirable accommodations as they were when built in 1935. At the time of completion they were described as "one of the finest, if not absolutely the finest, middle-class housing projects in the world"[13] Residents of the flats had the luxury of central heating and built in refrigerators, as well as the use of communal gardens and even a pool. Today one of the three bedroom apartments is up for sale for the indulgent price of £595,000.[14]

Applying the same principles to public housing on a budget was not always as successful. In Britain, the movement was often associated

with public housing more than anything else. It's collapse is often linked with the social problems residents of public housing estates commonly face. During the sixties and seventies, the political parties encouraged the building of high rise, high density tower blocks, which were then, an obvious improvement from the existing Victorian housing throughout the country. In the race to create modernist design solutions for all, corners were cut and substitutions made in design which could not be forgiven. Ronan Point is another example from London – a gas explosion unearthed weaknesses in the buildings structure, when one side collapsed dramatically in 1968. The public were shocked at the structural weakness of this pre fabricated tower and immediately questioned the stability of other high rise blocks which were defining the landscape. This, along with the demolishing of failed projects such as Pruitt Igoe, meant the public no longer had faith in the modernist movement.

### *Tasks to the Text*

- I. What is this text about?
- II. Define the type or combination of the types of the text.
- III. Make a model of the text.
- IV. Find key words.
- V. Make a graph of the text.
- VI. Put three questions to the text.
- VII. Write the summary of the text.
- VIII. Entitle the text.

### **Text 2**

#### *Pre-text tasks*

- 1. Read the title and the keywords, predict what kind of text it is and what the text is about.**
- 2. Read the Abstract and check your ideas**
- 3. Try to predict methods and techniques used for writing the text**

**Sustainability in the Civil Construction Sector Supported by Industry 4.0 Technologies: Challenges and Opportunities [19]**

**Abstract:** The civil construction sector is under pressure to make construction processes more sustainable, that is, aligned with economic, social, and environmental sustainability. Thus, the research question considers: How do Industry 4.0 Technologies help civil construction face challenges and identify new opportunities to become sustainable? The general objective of this work is to offer a current overview of publications that associate the civil construction sector; Industry 4.0 Technologies and sustainability, and identify the challenges and opportunities of the Industry 4.0 Technologies set to contribute to sustainability achievement. The research method was a bibliographic review combined with bibliometric analysis in SCOPUS databases. The results show that civil construction faces the challenge of reducing the consumption of natural resources, ensuring safe work, and optimizing processes, especially handwork. However, the insertion of Industry 4.0 Technologies into civil construction has allowed sensors, robots, modeling and simulation systems, artificial intelligence, and drones to have their productivity, efficiency, safety, strategic and environmental management enhanced. Furthermore, Industry 4.0 Technologies can contribute to civil construction through innovative, sustainable, and technological solutions focused on the flow of work, which can provide growth through the balance of costs/benefits in the management of projects and works. Thus, it is expected that this article will contribute to discussions around the possibility of construction becoming sustainable with the support of Industry 4.0 Technologies.

**Keywords:** technologies 4.0; sustainable construction; construction industry challenges; construction industry opportunities; sustainability; construction 4.0; intelligent construction; sustainability; industry 4.0; sustainable construction processes

## 1. Introduction

According to Lezoche et al. [1], the historical evolution of industry is marked by four phases, the first of which is referred to as the First Industrial Revolution, with the advent of steam machines and the use of coal as fuel. The Second Industrial Revolution stood out for the emergence of electric power and serial production lines. The Third Industrial Revolution provided automation of machines, computers, and the Internet.

Industry 4.0 appeared for the first time in 2011 in Germany and is referred to as the fourth industrial revolution [4]. This concept aims to integrate technologies such as the Internet of Things (IoT), Industrial Internet of Things (IIoT), Intelligent Objects, Big Data, Cloud Computing, Artificial Intelligence, 3D printing, Sensors, Actuators, Virtual and Augmented Reality [2,5] to create an environment of digital and intelligent manufacturing. Thus, the goal is to use these technologies to generate efficiency and optimize production processes continuously and upwardly by generating greater productivity, quality, and customization. The rapid advance in technological innovations in sensors, devices, information networks, and machine learning has helped robotics and automation progress rapidly, bringing improvements in several productive sectors [5]. In early 2020, during the COVID-19 pandemic [6] in Brazil, according to Zhou et al. [7] the use of technologies has shown its importance using Big Data in Geographic Information Systems (G.I.S.). Mainly regarding rapid visualization of information on epidemics, tracking of confirmed cases, transmission forecast, balance and management of supply demand of material resources [8] and the use of artificial intelligence (A.I.) to identify the transmissibility of the virus, populations at risk, and thus the ability to establish the infection cycle and suggest effective and preventative control measures [9].

All productive sectors are under pressure to develop their activities sustainably, based on environmental, social, and economic pillars, to promote the future of current and new generations. The continuous growth of cities and society elicits various concerns for improved development and management of the multifaceted urban systems, including resilience and sustainability [10]. Thus, considering these new scenarios and paradigms, the civil construction sector stands out, which is still regarded as unsustainable when employing archaic processes and activities, collection procedures, data recording, less automated and incomplete monitoring that results in waste of materials and exacerbated use of natural resources, beyond the unavailability of qualified labor [11]. However, sustainability was defined in the World Commission on Environment and Development's 1987 Brundtland report 'Our Common Future' as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' [12]. Since then, industries and business have also become part of the

search for the sustainability of operations so that they can remain profitable and positively impact society and with concern about the environment's ability to regenerate, thus, the American businessman Elkington, defines the Triple Bottom Line (TBL) concept determining three pillars: economic, social and environmental with a focus on the business perspective [13]. The implementation of the Sustainable Development Goals (S.D.G.s) since 2016, is strengthened through the S.D.G. 9–Industry, Innovation and Infrastructure, civil construction to actively participate in this universal call, in search of sustainable development, which contributes to a change in business and construction models supported by people and technologies [14]. This new model supported by construction, society and environment contributes to the attainment of the seventeen goals proposed by the U.N., since it affects the entire supply chain and brings improvements in resource efficiency, error elimination, reduction in waste of materials, energy and transportation (S.D.G. 7; S.D.G. 14; S.D.G. 15), as well as help achieve poverty eradication (S.D.G. 1) and zero hunger (S.D.G. 2), good health and well-being (S.D.G. 3), gender equality (S.D.G. 5), clean water and sanitation (S.D.G. 6), decent work and economic growth (S.D.G. 8), reduction inequalities (S.D.G. 10), sustainable cities and communities (S.D.G. 11), responsible consumption and production (S.D.G. 12) and direct actions against global climate change (S.D.G. 13) [11].

Some review articles related to the Civil Construction and Industry 4.0 Technologies were published. However, the review scopes are concentrated in just one industry technology 4.0, such as patterns and trends IoT by Ghosh et al. [15], extrusion-based additive manufacturing with 3D printing analyzed by Valente et al. [16], Sepasgozar [17] studied the Digital Twin application to expedite a smart and sustainable built environment, Darko et al. [18] explored Building information modelling (BIM) and appointed the survey and future needs, and Zhang et al. [19] identified Virtual reality applications for the built environment. Furthermore, the implications for the sustainability pillars are not the main research focus, thus there is a gap regarding the Industry 4.0 Technologies main contributions to the Triple Bottom Line. Although these studies contributed to the state of the art in Civil Construction and Industry 4.0 Technologies, this paper adds to these previous reviews the systematization of the Industry 4.0 Technologies set that can help us to face cur-

rent civil construction challenges and contribute to the identification of opportunities through practical examples in order to permit the sector to achieve sustainability.

Along these lines, discussions aimed at improving production patterns and using resources through new approaches, practices and innovative technologies that enable the construction sector to develop in a structured and sustainable way become essential. Construction 4.0 presents a promising initiative that helps other industrial sectors improve productivity indicators by optimizing operational processes using innovative technologies. Thus, the general objective of this work is to offer a current overview of publications that associate the civil construction sector; Industry 4.0 Technologies and sustainability and identify the challenges and opportunities of Industry 4.0 Technologies set to contribute to sustainability achievement. After this introduction, the paper is structured into five additional sections. Section 2 presents the literature review. Section 3 presents the research methodology. Section 4 presents the bibliometric results. Section 5 presents the discussion and systematizes the challenges and opportunities through a table and, finally, Section 6 presents the final considerations.

## **2. Literature Review**

Construction 4.0 is the application of the concepts of Industry 4.0 in the construction sector, that is, the application of digital technologies and processes adapted to the construction environment [20]. Construction represents one of the largest industries in the world, which contributes to around 13 percent of the global gross domestic product (GDP) [16]. In Brazil, the forecast of the civil construction sector's gross domestic product (GDP) is expected to increase by over 22 percent until 2025 [21]. However, this sector is responsible for the use of scarce natural resources [15], exacerbation of fossil energy source use even considering its limitation and delivery capacity [22]; increasing greenhouse gas emissions and global warming at large [23], energy consumption [17] generation of big quantities of solid wastes which are difficult to apply to waste management [24], and low use of technologies [25].

An abundance of research activity has been conducted to optimize civil construction utilizing Industry 4.0 Technologies, but review studies available on the topics are limited in terms of examples of using technologies and their final applications, and, mainly, in terms of the impli-



cations for the sustainability of the construction industry. Relevant studies review the use of only one technology in construction, such as IoT [15], 3D printing [26–28] and Virtual and Augmented Reality [19,27]. Others have reviewed a joint application of technologies such as BIM and IoT [17], Blockchain and BIM together in disaster recovery of buildings [29], or application of BIM to applications under construction in forum sites [30]. None of these studies present detailed discussions on the environmental, social and economic impacts of adopting new technologies in operations.

Nevertheless, some studies have comprehensively revealed the application of Industry 4.0 Technologies in construction [31–33]. However, these studies also have a limited scope in terms of Triple Bottom Line contemplate [33] which reviews the implications of adopting smart technologies for sustainable construction and the positive consequences for health, safety, and the environment. These analyses are restricted to operations carried out on site, that is, while the construction project is being carried out.

Thus, it is noted that the implications for sustainability are not the main target of the reviews conducted so far. Despite the growing interest in the application of Industry 4.0 Technologies in construction, there is a knowledge gap regarding contributions to the sustainability dimensions of the adoption of such technologies in the construction production chain [34]. The researchers are more focused on the technical aspects of [31]. Environmental, social, socio-cultural and ethical issues are yet under explored in research relating to the adoption of Industry 4.0 Technologies in civil construction [32].

### **3. Research Methodology**

To understand state of the art, identify knowledge and possible research gaps, the research method employed was an exploratory bibliographic review combined with bibliometric analysis [35]. To ensure transparency and traceability of the results reported here, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol [36,37] was implemented to conduct the research. The research was carried out on the SCOPUS database in February 2022, using the title, abstract and keyword options, applying the following query and boolean operators:

(1) “CONSTRUCTION” OR “CIVIL CONSTRUCTION” OR “CONSTRUCTION TECHNOLOGY” OR “CONSTRUCTION 4.0” OR “INTELLIGENT CONSTRUCTION”;

(2) “TECHNOLOGIES 4.0” OR “INDUSTRIES 4.0” OR “INDUSTRY 4. 0” OR “THE 4<sup>th</sup> INDUSTRIAL REVOLUTION” OR “THE FOURTH INDUSTRIAL REVOLUTION”;

(3) “SUSTAINABLE” OR “SUSTAINABILITY” OR “TRIPLE BOTTOM LINE” OR “SUSTAINABLE DEVELOPMENT”.

The approach has a qualitative character since it aims to deepen the knowledge on how the fourth industrial revolution can contribute to advances in civil construction.

#### **4. Results**

The search returned 113 publications, and after applying the filter, applications resulted in 42 articles and after reading and reviewing, 27 articles fell within the research, which were submitted to a systematic and bibliometric analysis through the VOSviewer software. There has been an evolution of the subject over the last few years, but few publications on the SCOPUS platform have addressed the specific keywords. The search covers articles published in journals peer reviewed between the years 2017 and 2022, before that, there were only two papers published in 2016 at conferences proceedings. There is an increasing trend in the number of publications over the last years, especially from 2021, increasing exponentially, with 69.2% of articles being published only in the previous year.

Note that most publications are in European and Asian countries, but there are very few articles that relate to construction, sustainability, and technologies 4.0. Thus far, there are no American publications. Among developing countries, including the BRICS members (Brazil, Russia, India, China, and South Africa), only Brazil and Russia have not contributed to the advancement of research in these areas. The lack of financial resources and a proper management system for construction, informal construction, and demolition waste represent the main challenges that developing countries need to face [64,65]. Although there is no Brazilian article that stands out in the analysis, Brazil is still a country that suffers from challenges in sustainable construction, such as lack of more efficient government policies, lack of specialized labor, productivity losses and time with routine construction, problems in the disposal

of construction waste and few uses and applicability of technologies 4.0 in favor of sustainable construction [66]. The publication's distribution is presented in Figure 3.

The most relevant publications on the subject are concentrated in articles, representing more than 40.6% of the total published in five years. The main areas of indexation of journals are Engineering with 25.3% of publications; followed by Social Sciences with 18.9%; Environmental Sciences with 13.7%; Energy with 12.6% and 29.5% distributed in small percentages among the other areas. This distribution reveals that the technical and academic areas are the most engaged in the growth process of Industry 4.0 Technologies, aligned with the concepts of sustainability and civil construction.

By using VOSviewer software, based on the network of 27 articles extracted from the SCOPUS database, the keywords density visualization presents the co-occurrence of keywords. The more keywords around the node and the higher their frequency, the deeper the color appears (shown in yellow in Figure 4. It can be seen from the map that the top five keywords with high frequency in the research are: Industry 4.0 (18 times);

Sustainable Development (12 times); Sustainability (13 times); Construction 4.0 (8 times), and Innovation (6 times). At the same time, the others are a subset of it. The analysis of the nodes, which presents the strongest links on the map, reveals that current research aims to use technologies to help construction to achieve higher sustainability standards, thus contributing to sustainable development goals.

The secondary cluster with the higher density is composed of the keywords (innovation and strategic approach and management practice), signaling that the implementation of technologies in construction depends on a new innovative approach in relation to the strategic and operational activities of the construction. This is also reinforced by the proximity to the term (digitalization), the core of the industry 4.0 concept.

There are also weaker links and intensity, these being mainly constituted by keywords related to individual technologies (3D printing; building information modeling; sensor networks) and managerial practices that can operationalize the themes of the central cluster. Technologies that are used together appear close to each other, for example, the

terms (Blockchain and IoT) share a strong link since Blockchain technology is being implemented in IoT-enabled digital systems to avoid data and information vulnerability that travels over the Internet. Likewise, the terms (additive manufacturing and 3D printing) are due to 3D printing being the most used technology for additive manufacturing.

In addition, there is a concern with the sustainability of constructions gaining strength through the terms (life cycle analysis and manufacturing and building construction and sensor networks), which also indicates a change in the standard of assessment of environmental impacts in the construction industry, where the use of emissions data and resource consumption are collected with the help of sensors to feed environmental impact assessment systems.

The main result of the bibliometric review presents a description of the applicability of Industry 4.0 Technologies associated with civil construction. As shown in Figure 5, the revolution seen in the construction industry is marked by the adoption of disruptive technologies. In the content analysis of the articles, we identified 15 Industry 4.0 Technologies applied in the Construction. The most investigated technologies in the literature are Building Information Modeling (BIM) and 3D printing and scanning, being analyzed in 12 articles each. Then, IoT and Artificial Intelligence, represent the next most investigated with 7 and 6 articles, respectively. This analysis shows that there are many gaps regarding the implementation and impact of many technologies in the context of construction.

## **5. Discussion**

The construction industry plays an essential role in a country's economic growth, mainly in developing countries such as Brazil, where the construction sector represents one of the largest sectors of the global economy, employing about 7% of the population every year [48]. However, civil construction has been criticized for activities and processes that generate a loss of materials, overuse of natural resources, high volumes of waste whilst obstructing achievement of the sustainable development goals (S.D.G.s) goals [67].

In highlighting the civil construction sector, it is necessary to understand that it is an area facing many challenges in maintaining its activities and consequently in achieving sustainable development goals, given that the construction production chain significantly impacts the

three pillars of sustainability. Furthermore, construction remains one of the least digitalized and innovative sectors in using Industry 4.0 Technologies. It is only ahead of agriculture, which occupies last place in the McKinsey Global Institute Industry Digitization Index [68]. Although construction is moving towards automation, it still has no links to promising topics such as sustainability [69].

The construction sector bears the highest rates of work accidents worldwide, improving the implementation of technologies can be seen as a social solution to the health and safety of workers [33]. Technologies for information management and visualization are instrumental in enhancing human perceptions and interpretations of complicated project information [70]. Furthermore, an essential contribution of the industry 4.0 technologies use in construction lies in the possibility of automated data collection for environmental impact assessments in a life cycle approach, called Life Cycle Assessment (LCA). In LCA studies, the availability of specific data, inputs and outputs associated with the production of materials, products and processes is a challenge for the execution of reliable studies. The lack of data compromises the quality of the study and the validity of the results found. Thus, [61] propose a framework in which BIM can automate data collection and LCA studies in the context of construction, allowing recognition of the environmental load of materials, processes and operations and direct design improvements to reduce such impacts. Data collection for the LCA is operationalized through the integration of sensors and IoT enabled devices to BIM [57]. Green BIM for environmental sustainability can be used for monitoring and management over a building's full life cycle, and should then be considered in future research [71].

The adoption of Industry 4.0 Technologies can support the construction industry to implement Circular Economy standards and consequently achievement of the S.D.G.s, promoting resource efficiency from project inception to end-of-life. By incorporating circular design requirements into the technologies, such as design for disassembly, deconstruction, and recycling, it is possible to reduce the use of non-renewable natural resources, properly manage the waste stream, and close the materials loop [43,72].

*Practical Implications and Future Directions*

The contributions from the abovementioned reinforce the present article on the challenges and opportunities regarding the usage of Industry 4.0 Technologies, which can help the construction sector and bring improvements in sustainability concerning social, economic, and environmental pillars. Moreover, this highlights that the subject needs further attention by the academy, as there remains an extensive effort required in research related to the topic.

After carrying out the bibliographic research, identifying the selected works and developing the bibliometric and content analysis, several issues can be highlighted in relation to the concept of Construction, Industry 4.0 technologies, and Sustainability. The results revealed a growing field of research and trending topics that will gain more relevance. However, they also indicate that individual technologies are not well connected to sustainability initiatives, with a limited number of experts operating somewhat in isolation and who offer single-point solutions, mainly technical solutions, instead of taking an integrated management “holistic” approach necessary to plan new industrial and residential projects around the world.

Despite the contributions, it is understood that there are limitations in our study, since it qualitatively reviews, that is, only subjectively. Our review analysis is limited by search terms applied only in the Scopus database. The use of certain keywords and selection criteria defined in journal articles and in English bears some restrictions, therefore, all literature that includes publications in other languages and other forms of publication are not reflected in this study. While these limitations present useful avenues for future research to explore and expand on the results of this study, future studies may also focus on expanding the keyword set and use other types of publications, databases, and books, even news with ideas and practices that remain out of the analyses. Another important point is the development of empirical research covering different professionals in the civil construction stakeholder chain and at the strategic, tactical, and operational levels. Therefore, we wish to emphasize the lack of studies focusing on or integrating different Industry 4.0 Technologies highlights gaps such as:

1. The publication’s analysis distribution per year reveals that the interest in adopting Industry 4.0 Technologies in construction has

emerged within the last five years, being still a “hot topic”, with few theoretical and empirical investigations;

2. Thus far, there are no American publications. Among developing countries, including the BRICS members (Brazil, Russia, India, China and South Africa), only Brazil and Russia have not contributed to the advancement of research in these areas;

3. Lack the implementation and impact of many technologies in the context of construction; 4. How two or more technologies can be diffused, that is, worked together; or

5. There are still technical challenges related to the integration of different technologies. Future research should investigate the challenges encountered in the joint application of different technologies, both in theory and in practice;

6. Empirical studies with qualitative and quantitative approaches showing the real advances in the applicability of technological tools in construction;

7. The impacts of industry technology 4.0 affect which and how the pillars of sustainability operate;

8. Proposals for models that allow replicability within the topic’s construction, technology and sustainability;

9. Most articles explore the relationship between industry 4.0 technologies in construction from an economic and some environmental point of view, however, few also address the social pillar.

The practical implications of the results of the review allow future research efforts/activities in Industry 4.0 Technologies and sustainability in construction to be developed as discussed through this manuscript. The study benefits researchers and professionals in the construction industry. For researchers, the identified gaps reveal areas of high priority for future research, mainly highlighting the need to relate Industry 4.0 Technologies and sustainability of civil construction activities. Moreover, this study can help managers understand the integrations between Construction and Industry 4.0 Technologies to achieve better operational and environmental organizational results. For the construction industry, the study expands knowledge about available technologies and raises awareness of the latest applicability within construction and expands the potential to become a sustainable sector, which ensures good construction practices, is concerned with workers’ health and productivity,

and additionally preserves the environment and continues growth economically. The study exposes missing gaps from current research: a broader consideration of the construction adjustments needed to accommodate the use of Industry 4.0 Technologies to make the sector more sustainable. Therefore, these gaps in the literature should direct future research to strengthen the use of Industry 4.0 Technologies in construction to contribute to the sustainability and circularity dimensions of the processes.

## **6. Final Considerations**

The general objective of this work is to offer a current overview of publications that associate the civil construction sector; Industry 4.0 Technologies and sustainability, and identify the challenges and opportunities of the Industry 4.0 Technologies set to contribute to sustainability achievement. This study helps researchers and practitioners, with tables of reference that serve as a guide to advance the study of technologies and to address the current shortcomings of such technologies, while enhancing their sustainability contributions to processes in future building construction. To the best of the authors' knowledge, this study is the first of its kind using Civil Construction, Industry 4.0 Technologies, and Sustainability to propose a unified table to help managers and academics understand these relationships.

In the current scenario, where the civil construction industry continues to generate a large waste of resources such as water, energy and materials, the use of technologies can help improve the performance and competitiveness of the sector, in addition to contributing to achieving sustainable development goals. The central premise behind the use of technologies associated with Industry 4.0 is to generate efficiency and optimize production processes in a continuous and upward manner, that is, the use of resources in a reduced, precise, intelligent, and autonomous way, which generates greater productivity, quality and customization. Thus, from the bibliographic and bibliometric review, it is possible to verify that disruptive technologies support the new industrial paradigm, that can be applied in building, to improve the performance of the construction sector and render it more sustainable and intelligent using modeling systems and virtual simulation of projects, 3D printing, robots, drones, sensors, and the Internet of things (IoT).



The bibliometric review identified state of the art methods relating to Civil Construction; Industry 4.0 Technologies and Sustainability and pointed out that there are still few papers in this field and there remain gaps to be explored, not only by civil engineering, but by professionals and multidisciplinary researchers. Furthermore, it was noted that technologies are still secondary on the research topics, showing that there is space for them to be empirically explored and to become protagonists in the coming years. Another point is the developing countries, including Brazil, which are still adept at manual civil construction and poorly trained and digitalized, allows for growth in performance of the industry 4.0 technologies and Sustainability and solidification of the tools and practices that transform the current context. These findings also reflect in academic contributions, directing new lines of research in possible research gaps addressed in this article.

Through a bibliographic review of the literature, the research was able to point out what Industry 4.0 Technologies, challenges, and opportunities Civil Construction has experienced. From the review, it was possible to identify and present in a structured way the applicability of the industry 4.0 technologies within the scope of civil construction, by elaborating a comparison between the adoption of technological tools and the previous scenario of the sector.

That is why investing in technological intelligence means directing the strategy towards flexibility, which can significantly favor the civil construction sector, especially in issues of cost reduction, improvements, and alternatives to the productive process in search of transformation in the way of acting, thinking and doing. Therefore, it is concluded that Industry 4.0 Technologies can contribute to civil construction through innovative, sustainable, and technological solutions focused on the flow of work, which are able to provide growth to civil construction through the balance of costs/benefits in the management of projects and works. For future studies, the development of a systematic review of the literature is recommended, which can identify other opportunities and challenges, besides the practical and applicability of the use of new technologies aligned with the environmental, social, and economic pillars in the scope of civil construction.

### *Tasks to the Text*

- I. What is this text about?
- II. Make a model of the text.
- III. Make a graph of the text.
- IV. Put three questions to the text.
- V. Write the summary of the text.

### Text 3 [20]

#### 1. Introduction

Member states of the European Union are required to implement energy efficiency measures for buildings according to the Energy Performance of Buildings Directive [1]. With the new building codes, EU member states intend to reduce the total energy consumption in buildings by making them well-insulated and tighter. Due to the tighter and well-insulated constructions, the ventilation loads constitute a growing part of the heating demand, between 30% - 60% for new and retrofitted buildings [2]. As the ventilation heating demand plays an important role in the building's total heating demand, the exhaust air heat recovery is inevitable. It is possible to recover only sensible heat or both sensible and latent heat from the exhaust air [3]-[5]. Energy is used to cover the heat losses due to ventilation air and to move the ventilation air for mechanical ventilation. The main purpose of the study is to compare the different ventilation solutions of apartment buildings and assess their energy consumption.

The ventilation system also influences the air infiltration through the building envelope. A prerequisite for the construction of the mechanical supply-exhaust ventilation is sufficient air tightness of the building. If  $\varepsilon_{st}$  is the temperature ratio of the heat exchanger, in practice only part of the air flows through the heat exchanger [6].

This is the main reason why this phenomenon has been thoroughly studied. Since Kohonen *et al.* [7] published their experimental and numerical study concerning thermal coupling of leakage air and heat flows in the building envelope, the heat recovery effect between infiltration air and exterior walls has been studied by several authors, for example, [8]-[10]. In several countries, the air tightness of the building envelope is determined according to the type of the ventilation system. If the supply and exhaust airflows are balanced, the proportion of the infiltration is

higher than in the case when the room is positively or negatively pressurized. According to studies carried out in the UK [11], there is no considerable infiltration in case of exhaust air ventilation and building leakage rate  $n_{50} = 3\text{h}^{-1}$ . Almost all the air passes through the exhaust fan.

The paper presents the results of the investigations into the indoor climate and energy efficiency of different ventilation systems in residential buildings. The main types of ventilation in cold climate conditions are natural ventilation, mechanical exhaust ventilation, mechanical exhaust ventilation with exhaust air heat pump heat recovery, supply-exhaust ventilation with the apartment-based ventilation unit, and supply-exhaust ventilation with the room-based ventilation unit. The performances of the different ventilation systems in low-energy residential houses have been earlier presented by Maier *et al.* [12]. The energy performance of heat recovery units has been investigated by Jaber *et al.* [13] and Laverge *et al.* [14]. Ventilation heat recovery in residential buildings has been investigated by Doodoo *et al.* [15]. A number of studies on the ventilation and indoor air quality in apartment buildings have been carried out at Tallinn University of Technology by Mikola and Koiv [16]-[19].

The current research was conducted in 60 degrees of latitude (Estonia), where winter air temperatures drop to  $-20^{\circ}\text{C}$  or even lower. In these circumstances, efficient AHUs with heat recovery are necessary.

## 2. Method

To determine the effectiveness of various systems the following formulas are used. The thermal energy consumption for air heating is calculated based on the following correlation

$$Q=H\cdot S\cdot 24\cdot(1-\eta_Q) 10^{-3}\text{MWH} \quad (1)$$

where  $H$  – specific heat consumption for air change, kW/K;  $S$  – the number of degree days, d  $^{\circ}\text{C}$ , determined by the balance temperature of the building;  $\eta_Q$  —energy ratio for AHU, determined considering the location of the building and the temperature ratio of AHU. Specific heat consumption for air change is calculated by (2)

$$H=L\cdot\rho\cdot c \text{ kW/K} \quad (2)$$

where  $L$  – air flow rate  $\text{m}^3/\text{s}$ , average per day;  $\rho$  – density of the air,  $\text{kg}/\text{m}^3$ ;  $c$  – specific heat of the air,  $(\text{kJ}/\text{kg}\cdot\text{K})$ .

To determine the airflow rates, the demand-driven principle of AHU and the resulting airflow rates are taken into account. Electric energy consumption for heating the air is determined by (3)

$$E_1 = \Phi \cdot z \cdot 10^{-3} \text{ MWh} \quad (3)$$

where  $\Phi$  – power of electric heating coil, kW;  $z$  – working hours, h.

The electrical energy consumption of the fans of AHU with air piping is determined by the presumed SFP factor.

$$E_2 = L \cdot \text{SFP} \cdot z \cdot 10^{-3} \text{ MWh} \quad (4)$$

where SFP – specific ventilator power,  $\text{kW}/(\text{m}^3/\text{s})$ .

To determine the reduced energy consumption, the correction factor of electricity consumption 1.5 is considered.

The calculations were made in small apartments ( $50 \text{ m}^2$ ).

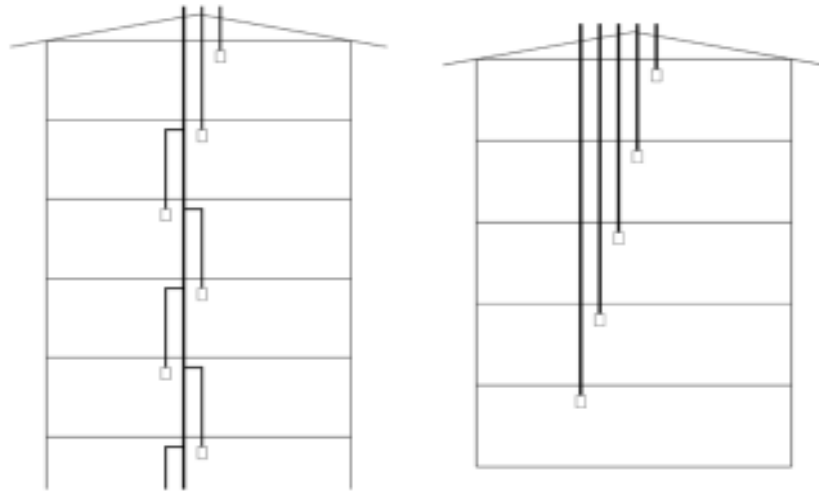
### 3. Results

#### 3.1. Natural Ventilation

Ventilation in old apartment buildings, as a rule, is natural.

Figure 1 shows two typical solutions of natural ventilation: the one on the left for typical 9-storey apartment buildings and the one on the right for typical 5-storey apartment buildings.

Natural ventilation operates due to the difference in the air density indoors and outdoors. Additional influence is exercised by the height of the ventilation channels and the strength of the wind.



**Figure 1. Solutions of natural ventilation for typical old apartment buildings.**

Natural ventilation is unstable in operation. During the periods of transition, especially in the summer, the air change is not sufficient, but it is often too intensive during the winter period, especially at low ambient temperatures.

### **3.2. Indoor Climate**

In apartment buildings the most serious problems caused by partial renovation are the facts that the walls and the roofs have been insulated and the windows have been replaced, but the ventilation has not been renovated. Some examples of indoor climate in partly renovated apartment buildings are given.

In the bedrooms of partly renovated apartment buildings very high relative humidity is observed, as can be seen in the Figure 2(a). Figure 2(b) shows the level of carbon dioxide concentration in the bedrooms of a partly renovated apartment building. It can be seen that the CO<sub>2</sub> level extends to 3000 ppm.

The formation of mold in the region of thermal bridges in apartments is quite common if the relative humidity is high.

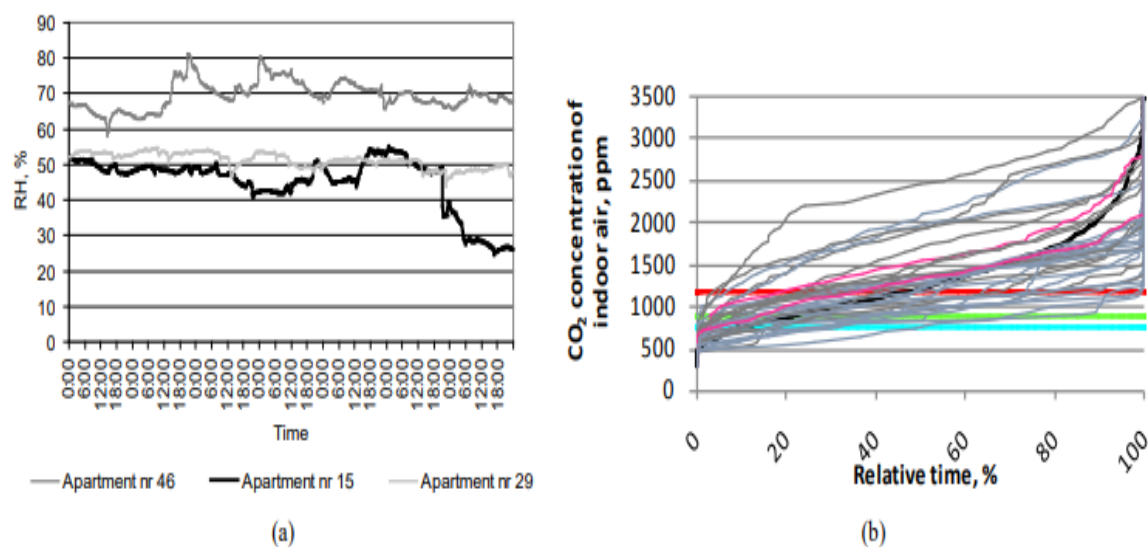


Figure 2. Relative humidity (left) and carbon dioxide concentration level (right) in the bedrooms of a partly renovated 60-apartment building in the winter time.

### 3.3. Ventilation Solutions

It should be noted that the renovation of ventilation in old apartment buildings is quite complicated. It is very difficult to ensure the required air change with the ventilation systems, the solution of which is acceptable for the tenants.

1) *Natural ventilation with fresh air valves*, Figure 3

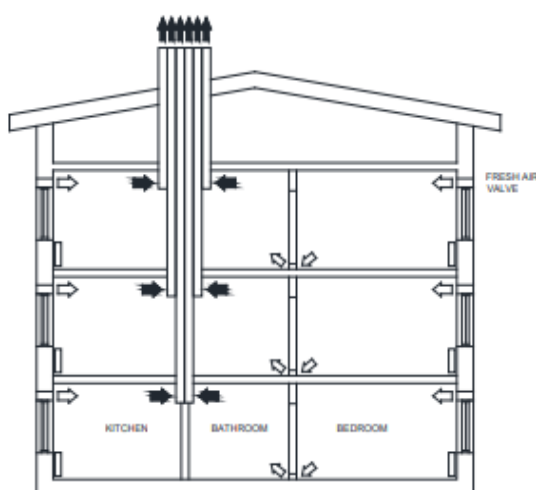


Figure 3. Natural ventilation with fresh air valves.

With that solution residents sometimes complain that fresh air valves cause cold air currents in rooms. A better solution is to use special heating coils, which are combined with fresh air valves.

The main disadvantages:

- High specific consumption of heat energy;
- At maximum loads the runoff of pollutants is not guaranteed;
- Air change is unstable: in practice there is no air change in summer, but in winter the air change is too high;
- Possible inconveniences of cold air inflow in the living space;
- External noise and pollution are carried indoors;
- At the maximum loads good indoor climate is not guaranteed for the majority of the year.

Good qualities:

- Absolutely no noise;
- Minimal investments.

The approximate annual specific reduced energy consumption is 2.5 MWh per year if the air change rate  $n = 0.57 \text{ h}^{-1}$ .

## 2) *Mechanical exhaust ventilation*

This is used in a newer type of apartment buildings (built between 1990-2012), Figure 4. This system ensures good air change and air quality, but is very expensive in operating costs. The air heating cost in such a system is about 50% - 70% of the heating costs. The approximate annual specific reduced energy consumption is 3.7 MWh per year.

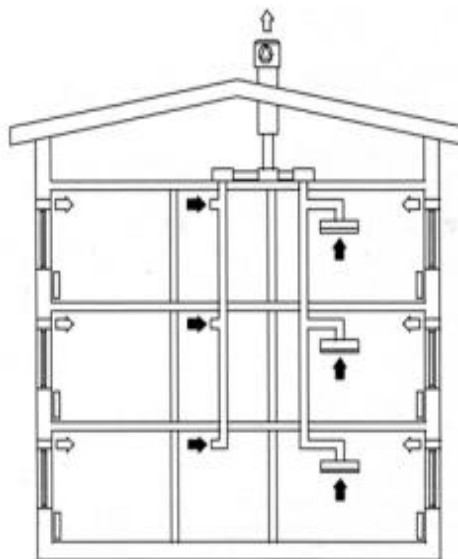


Figure 4. Solution with mechanical exhaust ventilation.

The main disadvantages:

- Energy consumption is greatest;
- Possible unpleasantness of cold air inflow in the living space;
- External noise and pollution are carried indoors;
- The maximum loads for ensuring good indoor climate will increase.

Good qualities:

- Compared with natural ventilation, stable air change is guaranteed throughout the year.

The following solutions have heat recovery.

### 3) *The apartment air handling unit*

Figure 5 shows the ventilation solution with the apartment air handling unit (AHU).

The main disadvantages:

- For a small apartment it is relatively expensive;
- Expenditure on exchanging filters.

Good qualities:

- Ensures very good indoor air quality;
- In large apartments it is also economically justified.

It is widely used in detached houses as well as new apartment buildings. It is problematic to use in old apartment buildings as people do not like installing ducts in the flat. The approximate annual specific reduced energy consumption is 1.9 MWh per equivalent apartment if  $SFP = 2$  for small apartments and 2.5 MWh for large apartments.

### 4) *The use of central balanced ventilation, Figure 6*

The main disadvantages:

- Ventilation air ducts in the apartment;
- AHU and air ducts on the staircase;
- The risk of noise;
- Requires very good design and construction;
- Problems with duct installation and sometimes with noise;
- Expenditure on exchanging filters in the AHU.



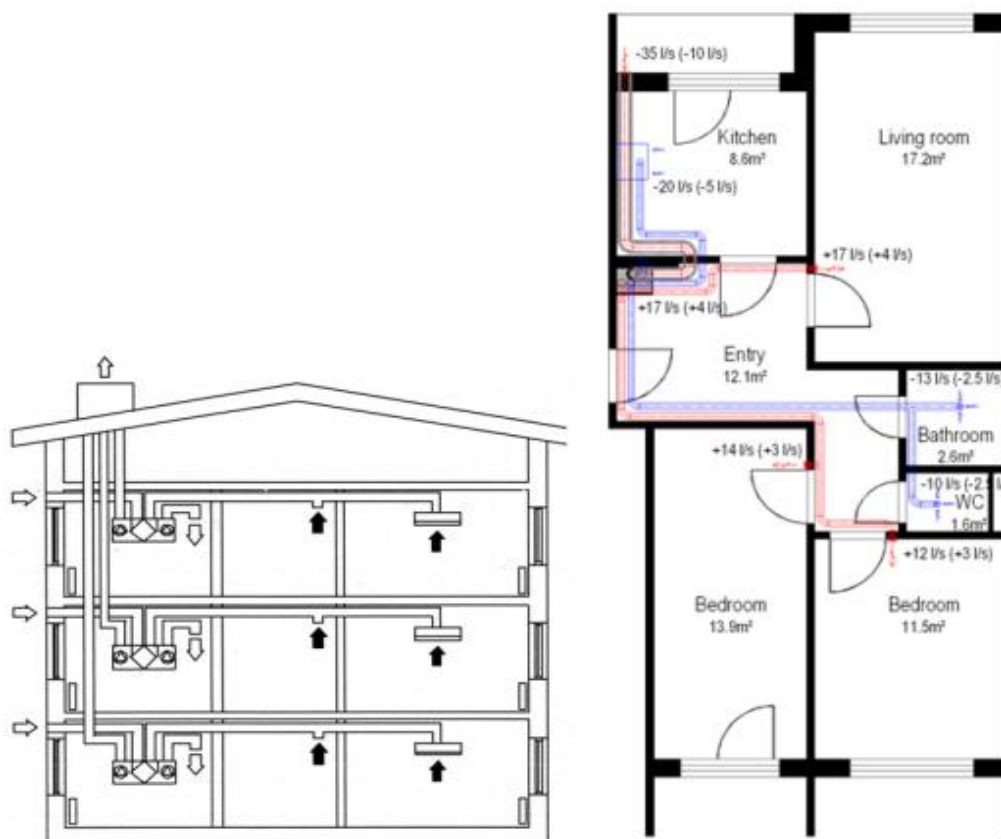


Figure 5. Principal solution (left) and apartment plan (right) of apartment solution.

Good qualities:

- Ensures very good air quality;
- Suitable for small (2 - 3-storey) apartment buildings with a suitable space solution of the apartment.

In practice it is possible to use central balanced ventilation in smaller apartment buildings, installing AHU and ventilation ducts on the staircases. The annual reduced energy consumption is 2.0/2.6 MWh per equivalent apartment if SFP = 2.5 (small/large apartments).

5) *The use of the room AHU and programmable exhaust ventilators in the WC, bathroom and kitchen*

Ventilation solution with the room AHU has recuperative heat recovery (for example Meltem AHU).

When testing Meltem AHU, in the range of outdoor air temperature from +5 to -20°C, the average temperature ratio (efficiency) was between 40% to 65%, with an average of 60%.

The main disadvantages:

– At the ambient temperature of below  $-18^{\circ}\text{C}$  the frost protection device turns the unit off;

– AHU  $410 \times 390$  mm is in the living room;

– Additional costs on exchanging filters;

At night with restrictive noise limits the guaranteed air flow rate is up to  $40 \text{ m}^3/\text{h}$ .

Good qualities:

– Demand-based ventilation with heat recovery is guaranteed;

– Good economic indicators for small apartment buildings.

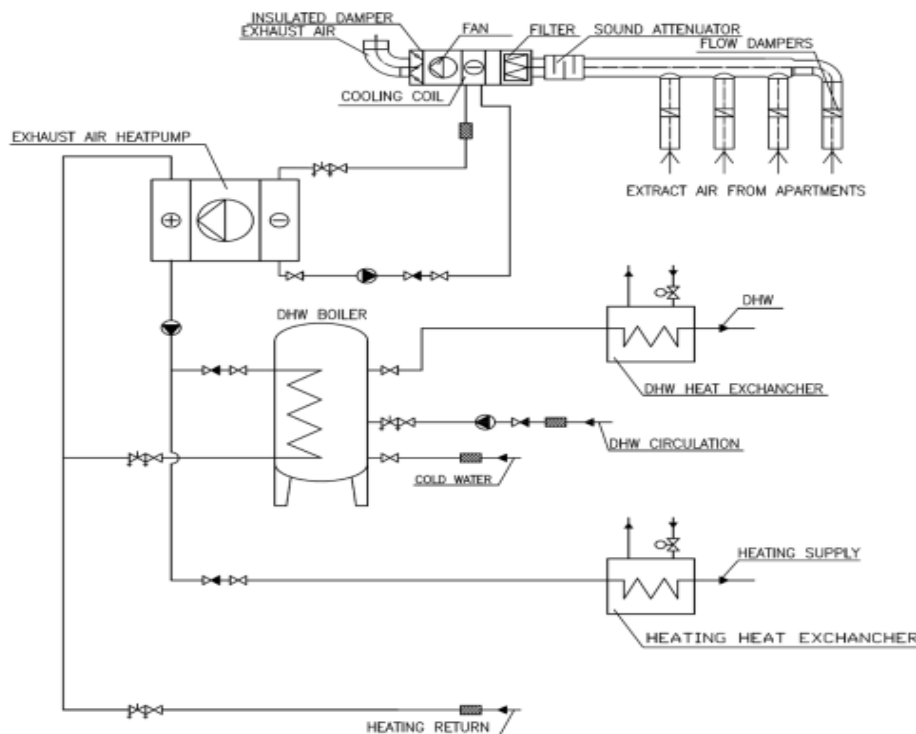
The approximate annual specific reduced energy consumption is  $1.3 \text{ MWh}$  per equivalent small apartment ( $1.9 \text{ MWh}$ —for large apartments).

It would be practical to ensure central exhaust ventilation from the WC, bathroom and kitchen during the time when they are not used with the pressure controlled exhaust ventilation system (on the roof).

Tenants' evaluation of the use of Meltem AHU in apartments has been very positive.

#### 6) *The exhaust air heat pump system*

The principal diagram of the unit is shown in Figure 6. Fresh air is sent to rooms through fresh air valves.



**Figure 9.** Principal diagram of the exhaust air heat pump.

The mechanical exhaust ventilation system together with cooling batteries allows using the thermal potential of the exhaust air.

The main disadvantages:

- Requires very good design, construction, adjustment of the air-flows, and maintenance;
- With the maximum pollution loads of the WC, bathroom and kitchen it is difficult to ensure the necessary air change;
- It is possible that there is some unpleasantness of cold air in-flows in the living rooms;
- Outside noise and pollution are carried indoors;
- Requires the existence of ventilation flues, which are at least in a satisfactory condition;
- For efficient operation of the heat pump, the heating system must have a reduced temperature graph;
- The payback time of investments is relatively long;
- It is necessary to adjust the exhaust ventilation airflows in the apartments;
- In cogeneration districts during the summer period the energetic feasibility is questionable;
- Additional costs of exchanging filters.

Good qualities:

- The construction work in the apartments is relatively small;
- The average COP was 2.6 and the share of heat production of the heat pump was 47.3%.

In summer the share of the heat pump in the heat supply of the building was about 90%, the COP was 3.1.

The approximate annual specific reduced energy consumption is 2.3 MWh per equivalent small apartment (3.0 MWh – for large apartments).

#### 7) *Room-based regenerative AHU*

This AHU has a regenerative ceramic heat exchanger. This is a paired device, each of which is typically located in a separate room. They operate intermittently, the air flows out for 70 s and in for 70 s. One of the devices provides the room with fresh air, the other removes the exhaust air, the latter also heats up the ceramic heat exchanger. The device has a very small ventilator. It should be noted that in laboratory conditions, where the regenerative AHU was tested, the system worked

well. In practical operating conditions in an apartment where in addition to the room AHU there is natural exhaust ventilation from the WC/bathroom and the kitchen, the efficiency of the system is very low. It should be noted that the intensity of natural ventilation plays an important role.

The main disadvantages:

- The risk of noise is very high;
- Outside noise and pollution are carried indoors;
- Its operation is directly dependent on working natural ventilation;
- In designing it is difficult to achieve effective functioning of the AHU on the lower and middle floors of the buildings and therefore, during the colder months there is practically no heat recovery. Thus, the suitability of the fan characteristic must be considered;
- Inconveniences of the cold air inflow into the living rooms.

Good qualities:

- Suitable for low, 1 - 2-storey buildings;
- The approximate annual specific reduced energy consumption is 2.1 MWh per equivalent small apartment (3.0 MWh – for large apartments).

### **3.4. Comparison of the Reduced Energy Consumption of Different Ventilation Solutions**

In small apartments the energy consumption is lowest with the recuperative room based AHU. In other systems, with heat recovery, however, it is similar. Thus, when making a choice, the characteristics of the system have to be considered, as the investments are quite similar for heat recovery systems, approximately €1000 -€1200 for small apartments. In large apartments, the investments in room-based systems are 2 times higher. In this situation, it is preferable to use centralized systems or the apartment AHU.

## **4. Conclusions**

The results of the study show that in the renovation of old apartment buildings, solutions with heat recovery must be used. However, the economic indicators of the solutions are somewhat different for small and large apartments.

In small apartments, it is suitable to use room-based solutions with recuperative heat recovery units, particularly in small and medium-sized

buildings. In large apartments, apartment-based AHUs would be both technically and economically perfect, provided that they are accepted by the residents.

In smaller 2-3-storey buildings, very good air quality and economic characteristics can be achieved with the central balanced ventilation system.

Despite some shortcomings of the system and the complexity, the exhaust air heat pump system could be used in renovating the ventilation in large apartment buildings. This solution is especially suitable for apartment buildings with mechanical exhaust ventilation.

When renovating the ventilation in old apartment buildings, it is necessary to pay special attention to the design, quality construction and supervision. Adjusting and maintaining the system are of great importance.

### **Tasks to the Text**

- I.** What is this text about?
- II.** Define the type of the text.
- III.** Define the scheme or combination of the schemes of the text.
- IV.** Make a model of the text.
- V.** Find key words.
- VI.** Make a graph of the text.
- VII.** Put three questions to the text.
- VIII.** Write a summary of the text.
- IX.** Entitle the text.

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