Effects of the Residential Built Environment on Remote Work Productivity and Satisfaction during COVID-19 Lockdowns: an Analysis of Workers' Perceptions

Abstract

COVID-19 pandemic has forced people to stay home and switch to the remote working mode, which – reportedly - affect job satisfaction and productivity. The present study investigates the relationship between the residential environment and worker's job satisfaction and productivity in the remote working mode during the COVID-19 pandemic. A hypothetical structural equation model (SEM) of the influencing factors is constructed based on a literature review and experts' opinions. A survey-based respondents' opinions (n = 2,276) were then used to test and analyze the model. The model results reveal that a residential built environment has an indirect effect on both remote work satisfaction and productivity. However, among all the factors, comfortable space (separate space and ergonomic furniture) is found to be the most important. This study presents the importance of adopting a residential built environment to respond to a crisis like a pandemic in achieving the desired comfort level of remote work. Although this study provides a holistic approach, it also proposes a base for the future country-specific analysis by providing some possible countries' differences.

Keywords: Teleworking; Job satisfaction; Pandemic; Structural Equation Model (SEM); Remote work; Productivity

1. Introduction

COVID-19 pandemic has abruptly altered people's lives globally by forcing them to spend most of their time at home to prevent the virus spread. Thus, the pandemic has altered the very definition of living space, as – for many – the dwellings become offices and classrooms, gyms, and more. This change has influenced residences' consideration of building sustainability [1–5], including building services [2,6–9].

In addition, many have been affected in terms of studying [10,11] and working [12,13] due to the forced lockdowns that have switched modes to remote.

Many countries have adopted teleworking with the introduction of COVID-19 lockdowns [14,15,24,25,16–23]. The remote working mode brought positive as well as negative perceptions from professionals who switched from the traditional way of performing their job. For example, the benefits of working from home are reported to be less burnout, a better work-life balance, and lower depression among female parents of underage children [26–28]. The challenges of remote working are associated with nervousness about the coronavirus pandemic and childcare [26,29]. In addition to these, different living conditions of people (e.g., family size, presence of children) have also been individually assessed to identify the level of comfortable workspace setting [26]. It is well documented that the remote workers' well-being [26,30,31], health [13,30,32,33], and productivity [13] have been affected during the pandemic. As such, the factors of indoor environment quality become even more critical when people are isolated in their homes; consequently, it is resulted in lacking socialization and being forced to continue their daily routines (working or studying) at their homes. Several studies shed light on the importance of the services and factors in the indoor environment of dwellings as an influencing factor in working from homes, such as green area [34], light, noise, and space layout [31,32]. Another study reports on the importance of the home layout as a lack of separation between living and working spaces can impact productivity [31]. Other factors that affected productivity were noise, low level of natural light, and absence of good scenery from home windows. It was also found that natural light affects eye health, while noise and air quality issues lead to increased stress rates along with decreased focus [31]. Humidity problems can adversely affect people's nose, throat, and skin, experiencing prolonged exposure [33]. Indoor air quality is one of the essential indoor environmental factors [32]. It was also found that the detrimental effect on the physical and psychological state of those who were working from home was mainly linked to such factors as sports, communication with colleagues, children, and workspace comfort [30].

There have been several attempts to research the impact of indoor and outdoor physical environments on human psychology [34]. However, to the best of the authors' knowledge, the collective effect of the previously reported factors has not been investigated. The relationship between the residential built environment and the remote workers' productivity and satisfaction during the extended COVID-19 lockdowns have yet to be investigated and quantified. Thus, this article aims to quantify the effect of the built environment parameters on workers' job productivity and satisfaction who need to work from home during the COVID-19 pandemic period. The following steps were taken to achieve this research aim: (a) to conduct an extensive literature review on the topic; (b) to develop a hypothetical model upon the review of the context; (c) to develop a structural model of the parameters and test its validity and reliability; (d)to develop built environment-related strategies and recommendations to improve workers' productivity.

2. Literature review

Indoor environments can initiate different physical and psychological issues among the residents. Continuously being at home can also affect working *productivity* and *satisfaction* through indoor environmental factors, such as *health and safety*, *ICT*, *comfort, and ergonomics*.

2.1. Identification of the critical factors

Health and safety. Health and safety in residential environments in the context of pandemics includes physical well-being, mental health, and protection from the viral transmission. Prevention of virus propagation and mental health were considered crucial characteristics of buildings during pandemics by the experts of medicine, academia, and industry [35]. Safety from virus propagation measures includes the use of new smart/innovative technologies that minimize personal involvement (e.g., touchless technologies, motion sensors, keycard swiping), self-cleaning spaces, and proper selection of indoor materials that do not facilitate viral and bacterial propagation and their increase in quantity [36,37,46,38–45]. Physical and mental well-being measures include household-level exercise spaces to improve both physical and

psychological body states, availability of outdoor spaces in the building (e.g., balconies) to get some fresh air and feel being outside even during strict lockdowns, and access to common building spaces with sufficient safety and social distance for socialization [5,47,48].

ICT. The main technological facilities used by remote workers are personal computers, the internet, and phone [49]. Adequate hardware facilities are essential for remote workers. Nevertheless, there could be a particular need for other work-related equipment, such as headphones, a microphone, a camera, or others—usually, companies who adopt remote working invest in provision with technological facilities [49]. Nevertheless, during pandemic lockdowns, the reliance on robust and adequate speed internet is growing, as most of the services (e.g., medical, product ordering, teaching and meetings) are switched to online, too [50–52].

Indoor environment working comfort and facilities. Working conditions, comfort, and ergonomic facilities are the critical determinants of the quality of the services provided by the residential built environment. It includes such criteria as light, noise, temperature, humidity, indoor air, comfort, and aesthetical indoor environment characteristics [4,5,32,53–58]. Therefore, to provide the building residents with comfort and good mental and physical health, it is vital to keep those indoor environmental factors on the desired levels. Other essential aspects highlighted in the literature include housing form, the facilities it has (e.g., a table, robust WiFi, an office space separated from the living area), and housing prices (like those with the office facilities are generally more expensive) [59].

Moreover, the workplace is strongly desired to be visually private [60]. Ergonomic furniture is another important feature of a comfortable environment for working – proper design can even prevent the rise of pain symptoms through a prolonged period of using ergonomic furniture [61] and is essential for supporting a productive working process [62]. Other research studies on working from home experience showed that workers desired better ergonomic spaces in their homes [26] and improved furniture [60]. Greeneries (indoor gardens and green views) could improve the mental state of residents [51,63]. Green space includes

indoor gardens, green views from the windows, and small gardens on balconies [44]. These could help people decrease their level of anger, provide relaxation, and decrease the chance of stress-related diseases such as cardiovascular illnesses and depression [33]. Availability of appropriate technologies and support from the workplace are claimed to improve the motivation and engagement in remote working [12].

Remote work productivity. Having an increase in productivity while working from home is still arguable. For example, one study in France revealed that only around twenty percent of the respondents indicated more productivity during remote working than in the office environment [49]. Other studies showed that people remotely working were more productive (around 80%) even when they got ill [64], and the workers' productivity enhanced over prolonged remotely work [65]. Women and workers of older age tend to be more productive during remote working [13]. In other available studies on remote working, productivity levels were not changed with the shift from office to home [13] or even decreased [66,67].

Nevertheless, better psychological and physical states were observed, and higher productivity levels were achieved among the workers [13]. Other factors that improved productivity were indoor temperature, the absence of small children, and a comfortable workspace [13]. Various methodologies and metrics were used in the literature studies to evaluate employees' productivity. For example, the work environment (physical and non-physical) effects on employees' productivity were investigated [68]. The parameters they used included Timeliness, Quantity, Quality, Attendance, and Ability to work in teams [68]. Other studies used indicators including, but not limited to, efficiency and effectiveness of work, creativeness, initiative, opinions expressed and generating new ideas [69–72]. Although the terms "performance" and "productivity have been used interchangeably, the current study uses "productivity" which is defined as "a measure of how efficiently resources are utilized to achieve desired outputs". However, it could be interpreted in different ways depending on the application context. In the remote work context, it can be defined as "successful and efficient execution of a project (by remote employee) and surpass of set goals in any

pleasing space". The present study adopts this definition to address the measured parameters identified in the theoretical framework.

Remote work satisfaction. The workers' desire to switch to remote mode is also unclear, as a small number of those find reduced commuting time and increased work-life balance as incentives to prefer remote working [73,74]. Nevertheless, it can be described by the fact that the workers adopt a stance that their management would not allow remote working; thus, they do not consider it [49]. In the United States, many workers would like to continue in the remote mode after the pandemic, too [75]. Remote workers tend to lose their satisfaction compared to traditional workers before the COVID-19 pandemic [75]. Factors that encourage the development of remote working are suggested to be categorized by the following: (1) the nature of the performed tasks; (2) the awareness of the advantages and drawbacks of remote working; and (3) reconcilability with the work culture [49]. Blurred time and the spatial boundary between work and personal life increase anxiety among remote workers, working hours, and focusing on professional tasks [26]. Moreover, increased autonomy during teleworking leads to an increased feeling of loneliness and, as a consequence, stress [76].

Nowadays, many factors might influence an employee's satisfaction with one's job [77], ranging from more objective parameters, such as salary, quality of supervision, and work & life balance, to more subjective ones, including personal values, sense of fulfillment and purpose, the realization of one's progress and sense of belonging [77]. Numerous academic and commercial studies were conducted to examine employees' job satisfaction. A study by Swarnalatha & Sureshkrishna (2012) showed that the job satisfaction of automotive industry workers in India used commitment, compensation, responsibility, achievement, supervisory support, workgroup cohesion, and quantitative workload to evaluate employees' satisfaction [78]. Other studies, such as Girma (2016) and Martins & Coetzee (2007), used some other metrics that include communication, diversity, fairness, job satisfaction, opportunities for growth,

productivity management, respect for employees, respect for management, teamwork, work/life balance [79,80].

2.2. Theoretical framework

The initial model, defining the relationships between the selected parameters, is proposed based on the extensive literature review. Health and safety, comfort and ergonomics, and ICT and other Enablers are identified as the primary physical parameters of the residential built environment impacting remote work productivity and satisfaction.

Safety from virus propagation, Mental health, and Physical health are chosen for further evaluation of Health and Safety in the residential buildings of the remote workers. Light, Noise, Humidity, Temperature, Indoor air, Comfortable working space, Ergonomic furniture, and Accessible greeneries are the indicators selected for assessing Comfort and Ergonomics [4,5,59,61,63,26,32,53–58]. They potentially help to evaluate the level of a comfortable and ergonomic environment of those who have worked remotely during the COVID-19 pandemic. The following indicators are chosen to assess ICT infrastructure among the remote workers; Adequate hardware, Other work-related equipment, Internet connection, and Company/ organizational support [2,49,51,52]. It is decided to focus on seven key productivity indicators to evaluate remote working productivity; Timeliness, Quality, Quantity, Impact, Efficiency, Engagement, and Team communication [13,49,65,68–72,81]. These indicators are chosen based on their relative ease of measurement from employees' perspectives and more objective metrics. Collectively, these indicators may effectively capture any key changes, should such occur, in employees' productivity. It is also decided to use four indicators to evaluate employees' job satisfaction during remote work: work-life balance (with regards to having enough time to sleep, exercise, and be with family), employees' preferred working mode (office vs. remote work), tolerance to salary reduction to be able to work from home, and overall job satisfaction. These indicators are assumed to be sufficient to build a general understanding of job satisfaction differences between office and remote work [49,73–75,78–80]. The third parameter, tolerance

to salary reduction, is unique since it aims to measure employees' willingness to sacrifice monetary benefits to keep the option of working from home, giving us an idea of the overall perceived value of working from home.

Following the literature review and initial selection of the parameters as discussed above, the identified factors and parameters were further discussed during a workshop that was conducted to finalize the model. The co-authors of the research represented different countries, such as Kazakhstan, Slovenia, Turkey, Romania, Poland, South Korea, the United Kingdom, Indonesia, and Malaysia. It achieved a rich discussion on developing the structural equation model and survey instrument. Thus, a conceptual structural equation model is developed and presented in Figure 1.

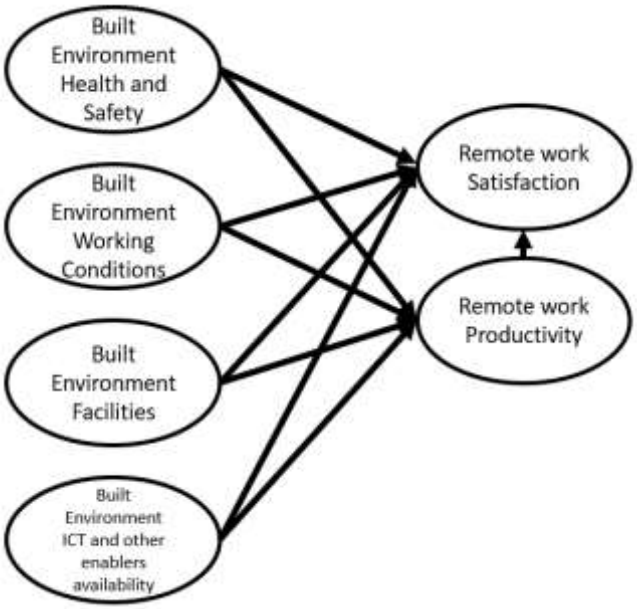


Figure 1. *Hypothetical model of factors influencing remote working*

Figure 1 shows the main inputs – *Health and Safety, Working conditions, Facilities, ICT, and other enablers' availability* in *Built Environment,* which leads to *Remote work productivity* and *Remote work satisfaction*. The list of latent and observable variables and their corresponding questions can be seen in Table 1. As this research study investigates the link between the residential built environment and

professional workers' productivity and satisfaction in the framework of remote mode, nine hypotheses have been developed. Each connection (arrow) in Figure 1 represents a hypothesized relationship between two factors, and overall the model contains nine main hypotheses, the direction/sign of each is assumed to be positive.

H1: Residential Built Environment Facilities influence Remote Work Satisfaction.

H2: Residential Built Environment Facilities affect Remote Work Productivity.

H3: Residential Built Environment Health and Safety impacts Remote Work Satisfaction.

H4: Residential Built Environment Health and Safety affects Remote Work Productivity.

H5: Residential Built Environment ICT & other enablers influence Remote Work Satisfaction.

H6: Residential Built Environment ICT & others improve Remote Work Productivity.

H7: Residential Indoor Environment Working Comfort affects Remote Work Satisfaction.

H8: Residential Indoor Environment Working Comfort impacts Remote Work Productivity.

H9: Remote Work Productivity affects Remote Work Satisfaction.

3. Methodology

3.1. *Survey Instrument and Data Collection*

The survey instrument was developed based on the reviewed literature and expert opinions obtained during the online workshops in October 2021. This workshop included representatives of academia (faculty staff) from different fields, such as civil engineering, mechanical engineering, materials engineering, ergonomic engineering, economics, and transportation, from several countries (Kazakhstan, Romania, South Korea, UK, Turkey, Slovenia, Poland, New Zealand). The brainstorming resulted in a mind map,

200 which can be found at the following link: https://miro.com/app/board/o9J_lq9Xg-I=/. Once the researchers
201 agreed on the final structure and content, it was submitted for the approval of the Nazarbayev University
202 Research Ethics Committee. The survey consists of 23 questions related to the proposed research model,
203 each of which is asked in the Likert scale format. Besides the model questions shown in Table 1, the survey
204 contains 11 socio-demographic questions related to the respondents' remote working experience during the
205 COVID-19 lockdown, such as; how long do they work remotely, where do they live, and what type of
206 residence do they live, the number of housemates they have, and whether there any children living with the
207 respondent, age, and gender. In the present study, productivity is measured based on self-assessment of the
208 workers. The questionnaire was translated into eight languages widely used in the regions covered by this
209 research and made available at the link https://nukz.qualtrics.com/jfe/form/SV_bIBwWADmmpZBgAm.
210 The data was collected via the online instrument Qualtrics from November – to December 2021. No specific
211 target group was aimed during data collection, so all the online working experience respondents were
212 welcomed.

213 ***Table 1.*** *Latent and observable variables*

Latent variables	Observable variables	Measuring question/statement
Health and Safety (BE H&S)	HS1. Safety from virus propagation	*My home is well protected against virus propagation*
	HS2. Mental health	*My home environment keeps my mental well-being in a good state*
	HS3. Physical health	*My home environment keeps my physical well-being in a good state*
Indoor Environment Working Comfort (BE WC)	C1. Light	*The level of natural light at my home is comfortable and sufficient for working at home*
	C2. Noise	*The noise level at my house is comfortable for working at home*
	C3. Humidity	*The humidity level at my home is comfortable for working at home*
	C4. Temperature	*The temperature level at my home is comfortable for working at home*
	C5. Indoor air	*The air at my home is healthy and comfortable*
Facilities (BE F)	C6. Comfortable working space	*a. There is a personal table at my home for comfortable working;*
		b. There is an office space separated from living space at my home;

	C7. Ergonomic furniture	*The ergonomic design of the furniture in my home does not cause me any pain or discomfort (e.g., pain in my neck, shoulder, back, eyes)*
	C8. Accessible greeneries	*I have access to greeneries (e.g., green views, green plants)*
ICT and other enablers availability (BE ICT & others)	I1. Adequate hardware	*I have sufficient hardware at my home (e.g., computer, laptop, tablet, phone)*
	I2. Other work-related equipment	*I have sufficient communication devices at my home (phone, microphone, camera)*
	I3. Internet connection	*I have adequate internet access and speed at my home*
Remote Work Productivity (RW Prod)	P1. Quantity	*I complete more tasks when remotely working than I do in the office*
	P2. Quality	*The quality of tasks I perform during remote work is better than in the office*
	P3. Effectiveness	*I had improved the impact of my work when I switched to remote work*
	P4. Efficiency	*I spend less amount of energy on the completion of a task during home working*
	P5. Engagement	*I engage more to work activities and meetings during home working*
	P6. Ability to work in teams	*I am more capable of working and communicating with a team during home working*
Remote Work Satisfaction (RW Sat)	JS1-JS4. Work-life balance	*I get sufficient work-life balance while working at home*
		I have enough time to sleep
		I have enough time to exercise
		I spend enough time with my family
	JS2. Preferred working mode	*If I could choose between working in the office or working from home, I would prefer to work from home.*
	JS3. Overall satisfaction	*Overall, I am more satisfied with working from home.*

3.2. Structural Equation Modelling (SEM) and Validity checking

For the evaluation of the reliability, validity, and further analysis of the model proposed in Section 2.1, the approach of Partial Least Square Structural Equation Modelling (PLS-SEM) has been utilized as a multivariate statistical tool for exploratory analysis of hypotheses and identification of the path weights (represented in Figure 1) with the utilization of SmartPLS program [82–84]. SEM is a statistical tool for measuring and further analyzing a model that represents relationships between observable and unobservable variables. Thus, through analysis of input manifested variables, latent variables and the relationship between latent and observable variables are measured. Each of the latent variables is measured through at

least three observables. For more precise analysis, a minimal quantity of manifested variables is better. PLS-SEM is a method used to evaluate compound relations, reasons, and consequences in path models with manifested and unobservable variables. Thus, this method is suitable to the scope of the study as it lets estimate the relationship between residential built environment factors and work from home satisfaction and productivity via manifested variables.

As per the PLS procedures, SEM reflective measurement model should be checked for its validity by checking the proposed model's (1) outer loadings, (2) Cronbach's Alpha (CA), (3) Dillon-Goldstein's rho (rho_A), (4) composite reliability (CR), and (5) Average Variance Extracted (AVE). Outer loadings represent the relationship between the latent indicator variable and its reflective construct, showing a strong relationship when equal to or greater than 0.7 [85]. While CA, rho_A, and CR are the unidimensionality checks that show how latent variables are consistent internally [86]. Similar to outer loadings, the minimal acceptable value for CA and CR is 0.7. AVE confirms that each latent variable converges while its minimum acceptable value is 0.5.

4. Results & Discussion

In total, 2,276 responses were received; among them, 1,918 were suitable for further analysis. The following criteria were used in the selection: the respondent answered positively that he was working remotely during the COVID-19 pandemic, and the response contained 70% of answers to questions on observable variables. According to Hair et al. [82], the minimum sample size should be ten times larger than the number of observed variables; therefore, our dataset fits the minimum sample size rule for the analysis of the SEM model. The respondents are from 35 countries. Figure 2 shows the Euro-Asian distribution graph with countries' contributions.

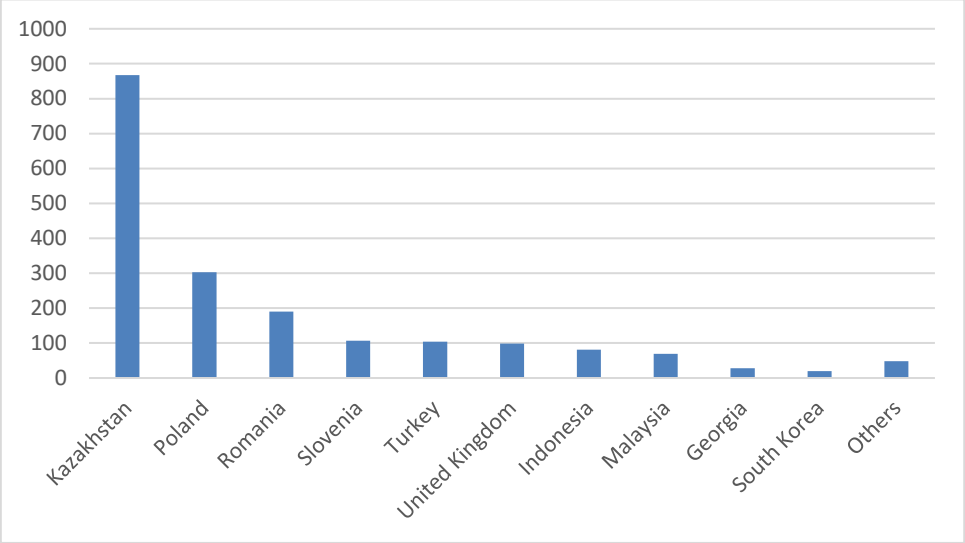


Figure 2. *Number of responses from contributing Euro-Asian countries*

The occupation types of the respondents are also presented in Figure 3. The majority (around 30%) is occupied in the education sector.. Other most prevalent in terms of responses working sectors are Business, consulting, management; Information Technology; Accounting, banking, and finance; and Engineering and manufacturing.

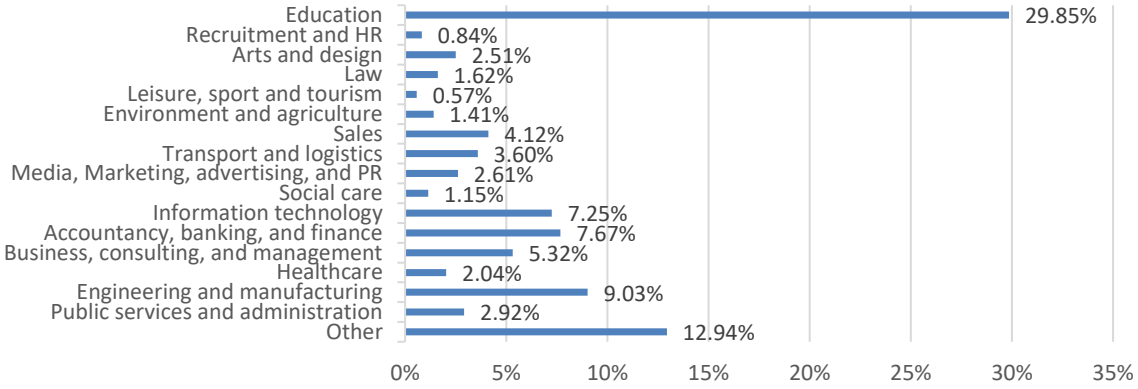


Figure 3. *Working sector representation of respondents*

Table 2 represents the socio-demographic characteristics of the respondents. The majority of the respondents (53%) stated that they had experienced remote working over a more extended period than six months, while only a minor group (10%) had it for less than a month. Most of the respondents are living in

urban areas (63%), in apartments (54%) with a total area of 50-75 sq.m. (33%). More than half of the respondents do not have underage children, while the age of the majority is between 20 and 30 (39%). Gender division is almost equal – 52% females and 47% males.

Table 2. *Socio-demographic statistics*

The remote working period of the respondent		
Less than one month	200	10%
1-3 months	391	20%
4-6 months	294	15%
More than six months	1031	53%
Living area		
Highly rural	238	12%
Rural	204	11%
Suburban/Metropolitan	260	14%
Urban	1214	63%
Type of residence		
Dormitory/shared room	45	2%
Apartment	1032	54%
Attached house	182	9%
Detached house	657	34%
The total area of residence		
Less than 50 sq.m.	338	18%
50-75 sq.m.	644	33%
75-130 sq.m.	576	30%
More than 130 sq.m.	358	19%

How many people respondent shares his home with		
Lives alone	145	8%
1-2 people	694	36%
3-4 people	764	40%
With five and more people	313	16%
Presence of underage children		
No	986	51%
Yes, 1 child	421	22%
Yes, 2-3 children	456	24%
Yes, 4 and more children	53	3%
Age		
Less than 20	168	9%
20-30	747	39%
31-40	565	29%
41-50	278	15%
More than 50	158	8%
Gender		
Female	1005	52%
Male	898	47%
Prefer not to say|Other	13	1%

4.1. SEM results, validity, and implications

The majority of outer loading scores in the constructed SEM are higher than the limit of 0.7, except for C8, HS1, and I4; nevertheless, their values are close. It leads us to conclude that the manifested variables are valid in their relations to the latent variables. Nevertheless, C8, HS1, and I4 values are close to 0.7. All other unidimensional values (CA, rho_A, CR, and AVE) also fall within the acceptable limits, see Table 3.

Thus, the model assessment shows that all SEM factors are validated and are suitable for further analysis. Figure 5 represents the developed structural equation model.

Table 3. *Outer model results and construct reliability and validity (Acceptance criteria: CA>0.7, AVE>0.5, rho_A>0.7, and CR>0.7)*

	Outer loadings	Mean	Standard Deviation	CA	rho_A	CR	AVE
C1	**0.755**	4.348	0.904	**0.846**	**0.846**	**0.890**	**0.619**
C2	**0.738**	4.044	1.087				
C3	**0.845**	4.281	0.911				
C4	**0.798**	4.450	0.809				
C5	**0.793**	4.384	0.838				
C6a	**0.740**	4.223	1.124	**0.743**	**0.766**	**0.838**	**0.566**
C6b	**0.776**	3.187	1.558				
C7	**0.836**	3.587	1.307				
C8	**0.645**	3.986	1.231				
HS1	**0.686**	4.166	0.940	**0.723**	**0.744**	**0.845**	**0.647**
HS2	**0.868**	4.240	0.913				
HS3	**0.847**	4.074	1.050				
I1	**0.856**	4.513	0.814	**0.778**	**0.778**	**0.872**	**0.694**
I2	**0.871**	4.483	0.846				
I3	**0.768**	4.211	1.053				
JS1	**0.792**	3.723	1.227	**0.862**	**0.869**	**0.896**	**0.589**
JS2	**0.743**	4.022	1.138				
JS3	**0.755**	3.717	1.237				
JS4	**0.737**	4.042	1.112				
JS5	**0.788**	3.452	1.428				
JS6	**0.788**	3.426	1.381				
P1	**0.779**	3.642	1.218	**0.902**	**0.904**	**0.925**	**0.673**
P2	**0.858**	3.526	1.195				
P3	**0.871**	3.460	1.199				
P4	**0.754**	3.621	1.254				
P5	**0.836**	3.377	1.281				
P6	**0.819**	3.263	1.277				

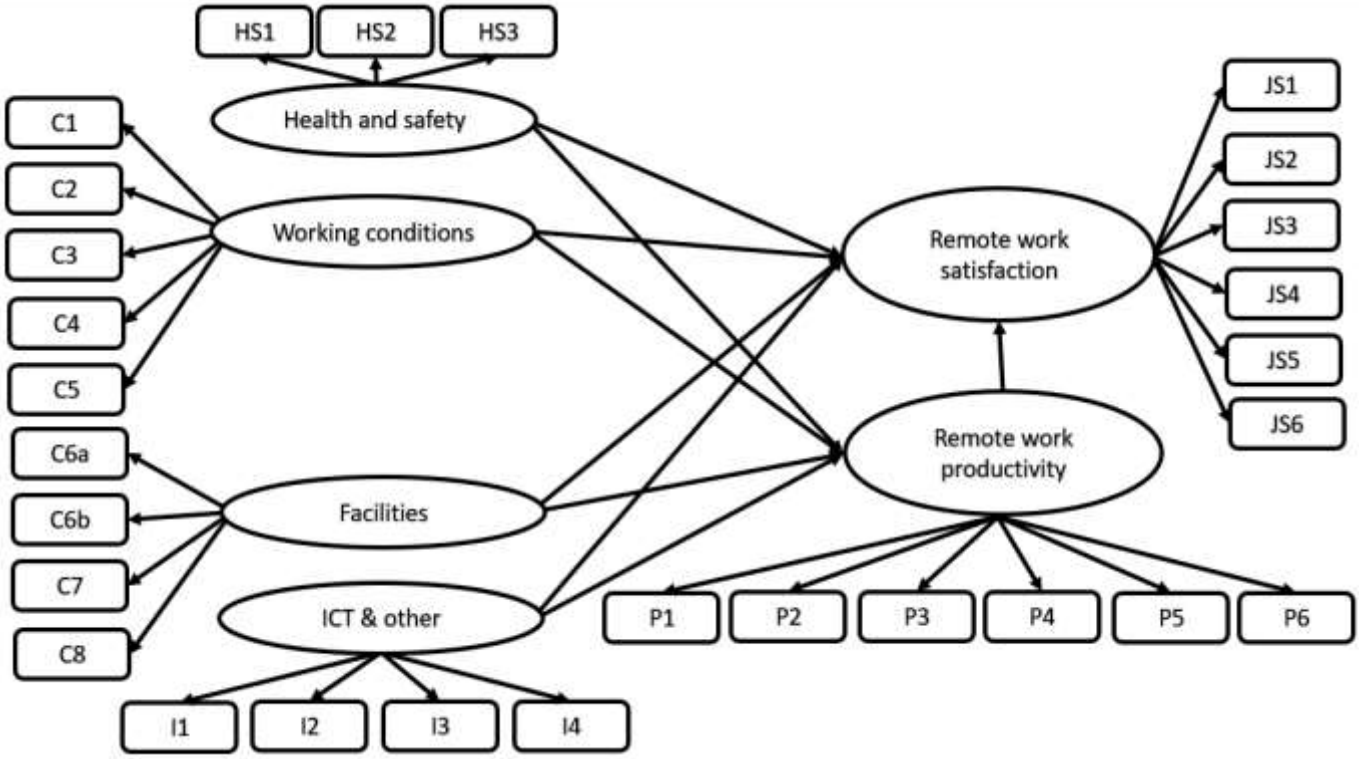


Figure 4. *Developed structural equation model in Smart PLS*

Discriminant validity (Table 4) is another important characteristic needed to be checked for the proposed reflective measurement model [82]. Discriminant validity shows how a construct is different from other constructs, which is seen by correlating it with other constructs, thus, seeing the extent of how many observable variables characterize a single construct. Since all the values in Table 4 are different from each other, this model is validated.

Table 4. *Discriminant validity of constructs*

	BE F	**BE H&S**	**BE ICT & other**	**BE WC**	**RW Sat**	**RW prod**
BE F	0.752					
BE H&S	0.484	0.804				
BE ICT & other	0.429	0.360	0.833			
BE WC	0.592	0.602	0.497	0.787		
RW Sat	0.420	0.377	0.346	0.394	0.768	

RW prod	0.438	0.351	0.315	0.349	0.692	0.821

As the main aim of this research study was to identify whether residential built environment conditions influence remote work satisfaction and productivity, it is important to test the model for the set hypotheses. It is done through analysis of the path-values (need to converge to 1) and p-values (need to be within 5% limit) [82]. As shown in Table 5, 8 out of 9 hypotheses are supported.

The only unsupported hypothesis is the path from built environment *working comfort* to *remote work productivity* (**H8**). Thus, it is not proved that the working comfort variables of the built environment (light, noise, humidity, temperature, and indoor air) lead to better teleworking productivity for the given sample. In contrast, in the study of Awada et al. [13], it is claimed that satisfactory temperature, air quality, noise, and lighting level correlate with better productivity levels during remote work; still, the correlation is weak. **H7** (0.072), which claims that built environment *working comfort* leads to better *satisfaction* during teleworking, is supported yet low. In contrast to a low score of H7, noise, air, and light are claimed to be very important in achieving workers' satisfaction in available literature [87].

The strongest path value is **H9**, which demonstrates that staying productive during remote work leads to better satisfaction. This finding is similar to the findings of Toscano and Zappala, which claim that feeling productive during teleworking makes people feel more satisfied with their remote job [66]. In the offline working environment, increased productivity is also proven to lead to better satisfaction [88]. Moreover, H9 shows that although the direct effect of the residential built environment on remote work satisfaction is low (as H1-H7 path values are small), the effect is much higher indirectly – through remote work productivity.

The second strongest hypothesis is **H2** (0.288), which connects built environment *facilities* and remote work *productivity*. Therefore, it shows that having an ergonomic workplace and greeneries is important for

301 the respondents to be productive during teleworking. Indeed, the available literature also proved that
302 dedicated working space and comfortable desks and chairs are associated with improved productivity
303 during remote work [13]. The availability of plants is also claimed to enhance productivity levels [89]. In
304 contrast, hypothesis **H1** has the lowest path value (0.036), which means that built environment *facilities*
305 have the lowest effect on remote work *satisfaction*. Thus, the observable variables of H1 - comfortable
306 working space, ergonomic furniture, accessible greeneries - are slightly influencing satisfaction with the
307 remote work. In another research, comfortable furniture is claimed to be crucial for the workers' satisfaction
308 [87], while greens tend to lead to happier workers [89].

309 Hypotheses on the effect of ICT have similar path values –**H5** (0.103) and **H6** (0.148). Thus, the effect
310 of *ICT* conveniences on remote work *productivity* and remote work *satisfaction* is similar for the surveyed
311 respondents. Similar to H5 and H6, other research also claims that adequate ICT resources positively impact
312 productivity [90] and work-life balance during COVID-19 pandemic teleworking [91].

313 **H3** (0.070) and **H4** (0.144), which represent paths from *health and safety* residential facilities to work
314 from home *satisfaction* and *productivity*, correspondingly, are also supported in the analysis of SEM. In the
315 authors' previous research, it was also found that health and safety facilities are important for remote study
316 satisfaction [10]. These findings are resonant with the available literature studies: health (both mental and
317 physical) are claimed to affect working productivity [13] and satisfaction [66]. During remote work in the
318 context of pandemics, workers feel safer from the virus at home, which leads to better satisfaction, yet,
319 social isolation decreases productivity [66].

320 ***Table 5.*** *Hypothesis test results*

Hypothesis		Path value	Original Sample	Sample Mean	Standard Deviation	P Values	Comment
1	**BE F -> RW Sat**	0.036	0.046	0.046	0.023	**0.046**	**Supported**
2	**BE F -> RW prod**	0.288	0.302	0.302	0.028	**0.000**	**Supported**

3	**BE H&S -> RW Sat**	0.070	0.072	0.072	0.025	**0.005**	**Supported**
4	**BE H&S -> RW prod**	0.144	0.148	0.147	0.027	**0.000**	**Supported**
5	**BE ICT & other -> RW Sat**	0.103	0.074	0.075	0.021	**0.000**	**Supported**
6	**BE ICT & other -> RW prod**	0.148	0.121	0.121	0.023	**0.000**	**Supported**
7	**BE WC -> RW Sat**	0.072	0.078	0.078	0.026	**0.003**	**Supported**
8	**BE WC -> RW prod**	0.016	0.021	0.023	0.028	**0.450**	**Not supported**
9	**RW prod -> RW Sat**	0.590	0.596	0.596	0.019	**0.000**	**Supported**

Additionally, we have received 428 comments from the respondents. Forty percent of the respondents emphasized the need for comfortable working space (C6), including the need for bigger space and moving to another home space. Twenty percent of them responded that they would like a better internet connection (I3) for more comfortable remote work. Ten percent needed more ergonomic furniture at home. Some of the remote workers expect their workplaces to support their workers by paying for the internet, hardware/software, and furniture for the comfortable working (10%), and through the increase of computer literacy of the workers, and having less stress from the office heads (2%). Five percent expressed that they prefer working in the office, and several respondents mentioned they need more social interaction during working. Five percent of the people that have experienced teleworking mentioned they had problems with light and noise in their residential environment. Two percent expressed their fears of worsening their health during remote working through increased screen time. Another 2.5% were craving better indoor air quality (C5), having more greeneries at home (C8), improved humidity (C3), and temperature (C4). Nine percent of the respondent would be more satisfied with remote working at home if they had better hardware – monitors or laptops (I1) - and other equipment – printers and scanners (I2). Due to blurred boundaries between work and home, three percent wanted improved work-life balance through fewer working hours and less work stress. The total percentage is higher than 100% because some of the comments expressed several points simultaneously.

4.2. Analysis by groups: by country, working sector, and gender

As the model has been validated, it was also interesting to analyze different groups (gender, country, and working sector) to find any deviating implications. Although the number of the collected dataset might not be sufficient to represent the views of the separate gender, country, and working sector, the research study still would like to find any possible features which might create a ground for further investigations.

Table 6 summarizes the SEM scores for different genders. For females to achieve satisfaction from remote work, built environment facilities, ICT, and working conditions are more important. The most substantial factor, among others, is comfortable working conditions. At the same time, males have better remote work satisfaction when their homes provide health and safety, ICT, and facilities. The most important factor, among others, is health and safety. To achieve remote work productivity, a built environment with comfortable facilities is the most important for both males and females. Moreover, females were found to be more productive than males, which is similar to the available findings [13].

Table 7 summarizes the results for different countries. For the remote workers in Kazakhstan, all the built environment factors have almost a similar effect on the satisfaction from remote work. Regarding productivity, built environment facilities are the most important, while built environment working comfort has a minor effect. Polish workers' satisfaction from working from home depends on built environment facilities and working conditions, while facilities and comfortable working conditions influence productivity. Slovenia is observed to have an equal effect on the latent variables on remote work satisfaction (except for health and safety, which do not influence at all). The productivity from remote work is also similarly dependent on the factors except for built environment working conditions, which do not affect productivity. Romanian workers find residential facilities and health and safety at home to not affect remote work satisfaction, while residential working conditions are the most important factor. In contrast, residential facilities and health and safety are the most important factors for productivity. Remote workers in Turkey find built environment facilities and ICT as the most influential factors in both remote work satisfaction and productivity.

Table 8 summarizes the analysis by working sector. For the workers involved in education during remote work, all four factors are similarly important for the satisfaction from remote work, while for productivity – facilities at home are the most influential. Accounting remote workers find residential facilities the most important factor for both satisfaction and productivity from working from home. Business sector workers, during remote work, find all factors have similar importance for remote work satisfaction. Compared to the Business workers, all four figures of the Education workers are smaller, which could also show that all four have little relationship with the residential environment. Whereas, for remote work productivity, BE F, BE H&S and BE ICT have more influence than others. The respondents representing the engineering sector are observed to find residential health and safety as the most influential factor in remote work satisfaction. The most affecting variables are productivity, built environment facilities, and ICT. For the IT workers, comfortable facilities and ICT are most influential on remote work satisfaction, while remote work productivity is most influenced by built environment facilities and health and safety.

Table 6. *SEM variables' scores for analysis by gender*

	Female		Male	
	RW Sat	**RW prod**	**RW Sat**	**RW prod**
BE F	0.085	0.315	0.085	0.289
BE H&S	0.047	0.143	0.113	0.152
BE ICT & other	0.080	0.134	0.046	0.103
BE WC	0.100	0.055	0.038	-0.025
RW prod	0.528		0.576	

Table 7. *SEM variables' scores for analysis by country*

	Kazakhstan		Poland		Slovenia		Romania		Turkey	
	RW Sat	**RW prod**	**RW Sat**	**RW prod**	**RW Sat**	**RW prod**	**RW Sat**	**RW prod**	**RW Sat**	**RW prod**
BE F	0.097	0.353	0.149	0.148	0.095	0.211	-0.010	0.330	0.144	0.380
BE H&S	0.092	0.155	0.009	0.000	-0.009	0.198	-0.039	0.204	0.070	-0.119
BE ICT & other	0.077	0.147	-0.019	0.034	0.030	0.158	0.069	0.046	0.096	0.209

BE WC	0.065	0.002	0.115	0.230	0.025	-0.059	0.188	-0.050	-0.006	0.037
RW prod	0.523		0.563		0.615		0.679		0.443	

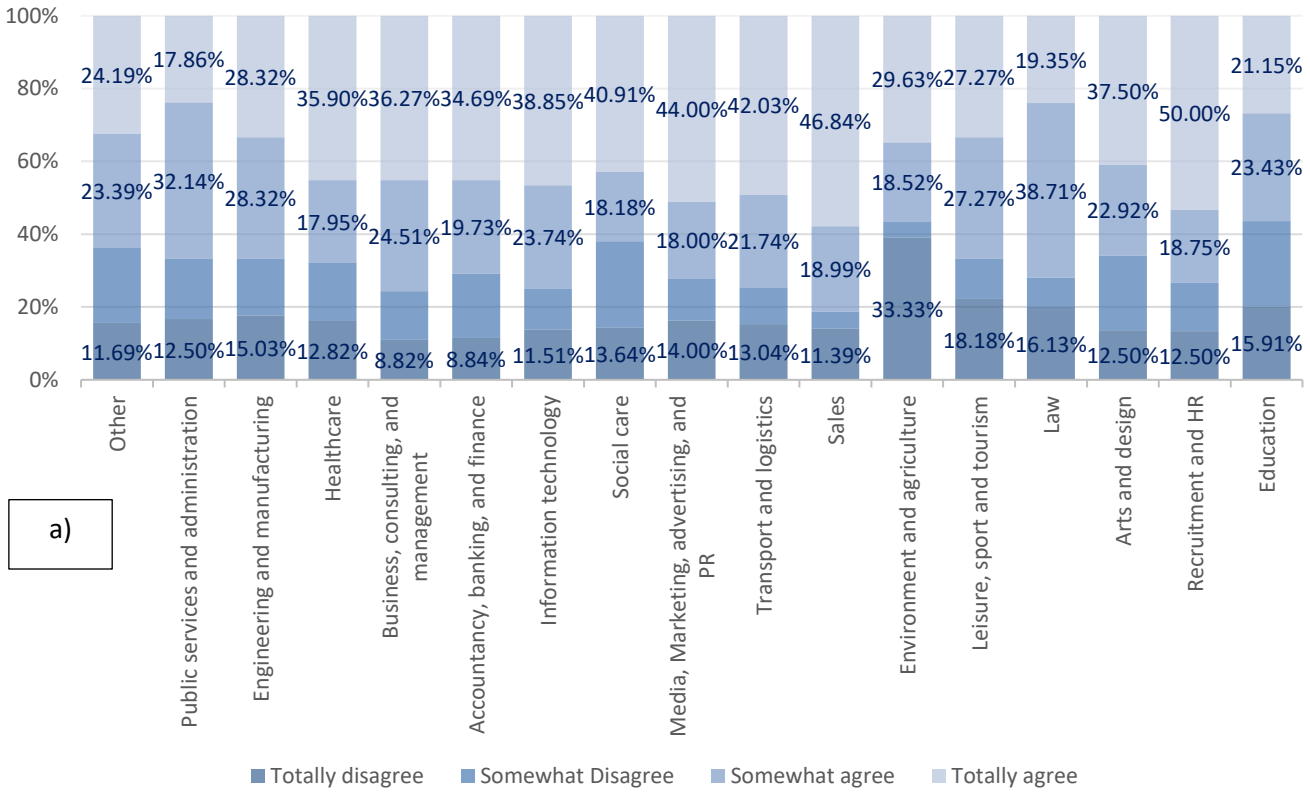
Table 8. *SEM variables' scores for analysis by working sector*

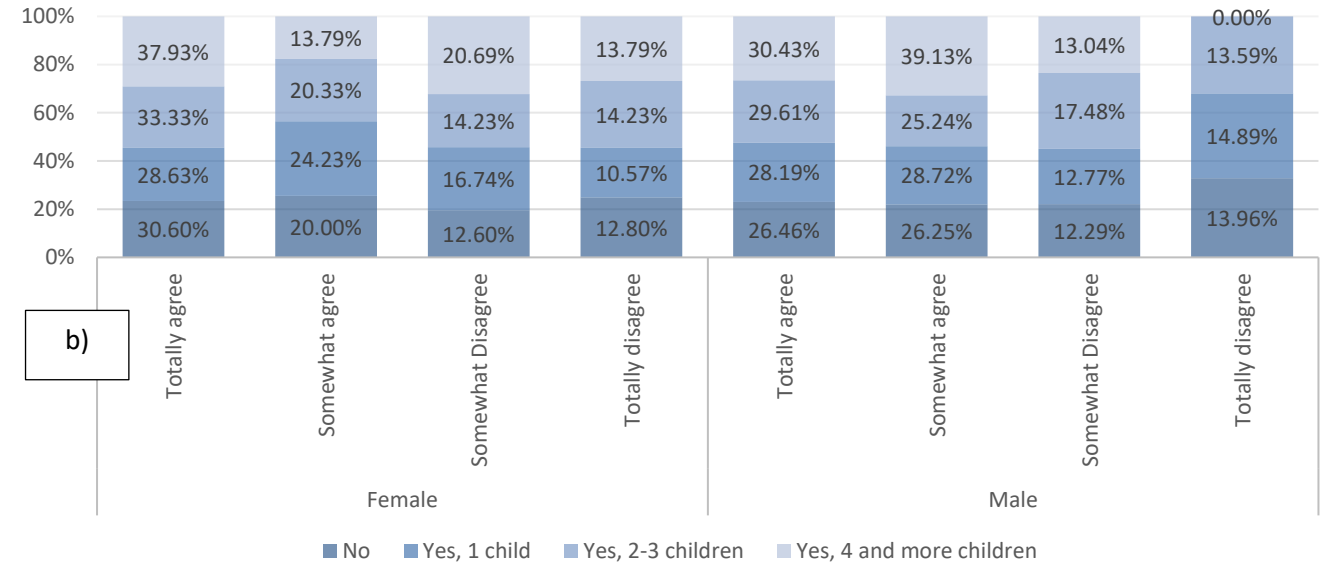
	Education		**Accounting,** banking, and finance		**Business**, consulting, management		**Engineering** and manufacturing		Information Technology	
	RW Sat	**RW prod**	**RW Sat**	**RW prod**	**RW Sat**	**RW prod**	**RW Sat**	**RW prod**	**RW Sat**	**RW prod**
BE F	0.110	0.328	0.292	0.614	0.121	0.151	0.068	0.302	0.195	0.280
BE H&S	0.063	0.121	0.010	0.163	0.093	0.200	0.149	0.088	0.095	0.249
BE ICT & other	0.010	0.076	0.179	0.148	0.044	0.198	-0.003	0.208	0.136	0.103
BE WC	0.062	0.048	-0.049	-0.160	0.126	0.012	0.085	-0.036	0.094	0.003
RW prod	0.56		0.343		0.575		0.633		0.451	

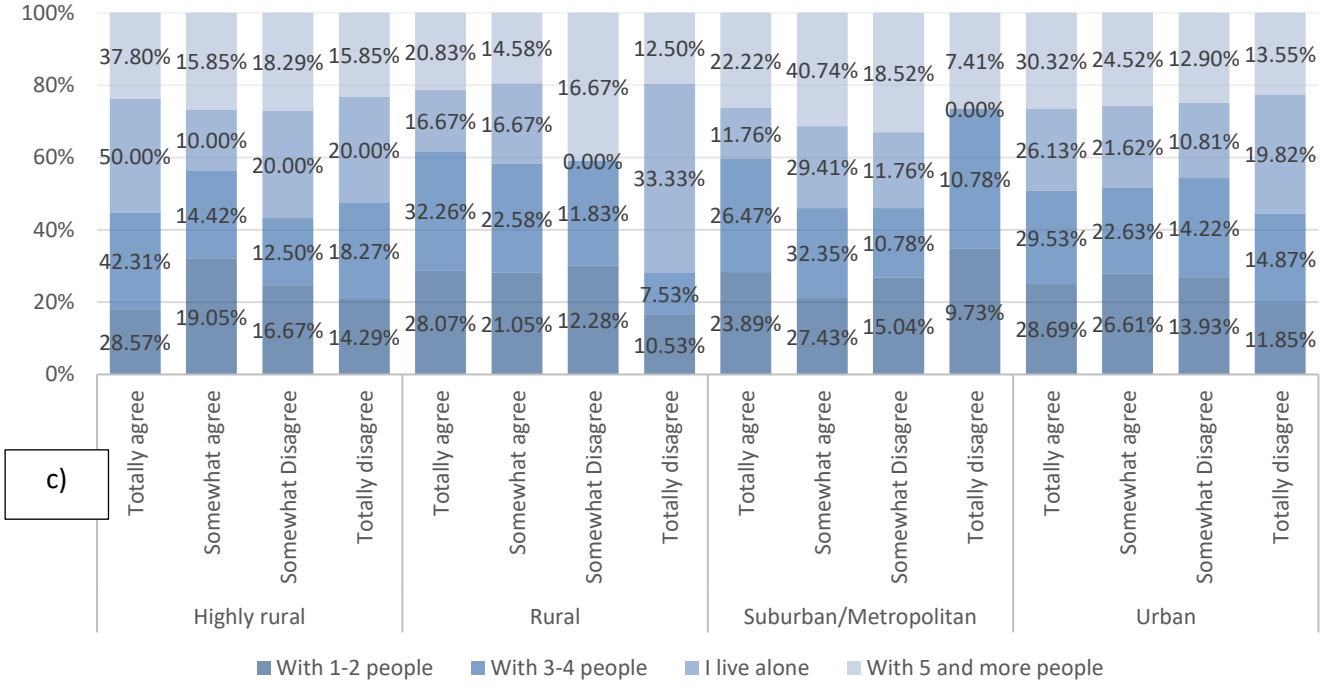
Figure 4 summarizes the general trends of the collected data from the respondents. The most satisfying remote working sectors are Recruitment and HR, Sales, Media and Marketing, and Transport and Logistics workers, while the most unsatisfying sectors are Public services and Administration, Law, and Education (Figure 3-a). The percentage of those who feel dissatisfied with remote work decreases the longer people work, except for those who worked remotely for less than one month.

Females and males with four and more children are most satisfied with working from home (Figure 3-b). These results are aligned with the earlier publications; for example, in the United States, females prefer more days working remotely [65]. Thus, some researchers claim it is important to assess gender roles in the environment that erases boundaries between office and living space, as women are generally more involved in unpaid domestic labor [59]. In addition, parents of underage kids are more likely to encounter problems during COVID-19 [75].

Those who live alone in rural areas are the least satisfied with remote working among all other groups. Respondents living in highly rural areas are the most satisfied with working from home, while those in suburban areas are the least satisfied. This trend is similar to the authors' previous research, where students residing in suburban areas were also the least satisfied with remote education [10]. The highest dissatisfaction with remote working is observed in the highly rural areas. This trend correlates with the quality of internet access, which was reported to be the poorest there. The better the internet access, the more satisfied respondents are with remote work. Better internet access, in turn, correlates with the degree of urbanization.







400 ***Figure 5.*** *a) Remote work satisfaction by working sector, b) Satisfaction with working from home*

401 *depending on gender and number of underage children living in the same residence, c) Satisfaction from*

working from home depending on the number of people the respondent shares his home with and living area type

5. Conclusion

The present study investigates the built-in effects of the residential environment on remote work satisfaction and productivity during the COVID-19 pandemic. A structural equation model (SEM) was constructed based on the literature review, hypothesizing a path relationship between the residential environment and remote work satisfaction and productivity. The SEM analysis indicated that the residential built environment indeed had an effect on remote work productivity and satisfaction, but its direct impact is not very large (the path values range from 0.016 up to 0.103). However, the indirect effect of the built environment on satisfaction through productivity was more substantial (path value 0.590). In more detail, factors such as 'Health and Safety' (safety from virus propagation, mental and physical health), 'Working Comfort' (light, noise, humidity, temperature, indoor air), 'Facilities' (separate from living and ergonomic working space, greens) and 'ICT' (equipment for work and internet) affect remote work satisfaction. Although the dataset is limited, this study also provided some possible gender-, country-, and working sector-specific features, which might be a basis for a more thorough and data-rich study in the future. In general, for different sex, countries, and working sectors, the most important factor was comfortable working facilities, which include comfortable working space, ergonomic furniture, and greeneries. These aspects have been further emphasized in the comments of the respondents.

COVID-19 has been a lesson for the whole world on living and working under total isolation beyond the accustomed ways of living and working. Thus, based on the SEM analysis findings and the comments from the surveyed, the following implications can be suggested for managers and teleworkers themselves to promote a better remote working experience. First, creating comfortable facilities for remote working is highly recommended. It includes separate working spaces with comfortable furniture and plants, as hypothesis H2 (effect of built environment facilities on remote work productivity) is the strongest among others, representing the built environment's effect on remote work satisfaction and productivity. Second, providing adequate ICT resources is important, including adequate hardware and robust internet. Moreover, respondents have noted that providing training on the use of ICT resources would be required for teleworkers. The third priority is to facilitate health & safety and working comfort for the teleworkers. These include providing a safe environment against virus propagation and having adequate mental and physical health, light, noise, humidity, thermal environment, and indoor air quality. Overall, SEM results imply that focusing efforts on workers' remote work satisfaction and productivity in these three areas would likely provide the highest return on investment of resources. In contrast, the hypothesis about built environment working comfort effect on remote work productivity is not supported during SEM analysis. Thus, light, noise, humidity, thermal, and air comfort are found to be non-priority factors in pursuing better teleworking productivity.

The present research provides insights regarding the effect of the residential built environment on remote work satisfaction and productivity. The constraints of the study include a limited number of respondents from certain countries and the bounding of the study by selected variables – built environment, remote work productivity, and satisfaction. We suggest conducting a rigorous country analysis with more responses collected in future studies. It is possible that in this study, people provided opinions depending on their conditions, as we collected the data during wintertime, while the responses might be different

during other seasons. In future studies, the researchers could also do a similar study in another season. In addition, age can be used as a moderative parameter for SEM

Funding: The authors acknowledge the financial support from the Nazarbayev University Faculty Development Competitive Research Grant Program (Funder Project Reference: 280720FD1904).

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Reference list:

1. D'Alessandro, D.; Raffo, M. [Adapting the answers to new problems of living in a changing society]. *Ann. Ig.* **2011**, *23*, 267–274.

2. D'alessandro, D.; Gola, M.; Appolloni, L.; Dettori, M.; Fara, G.M.; Rebecchi, A.; Settimo, G.; Capolongo, S. COVID-19 and living space challenge. Well-being and public health recommendations for a healthy, safe, and sustainable housing. *Acta Biomed.* **2020**, *91*, 61–75, doi:10.23750/abm.v91i9-S.10115.

3. Capolongo, S.; Rebecchi, A.; Buffoli, M.; Appolloni, L.; Signorelli, C.; Fara, G.M.; D'Alessandro, D. COVID-19 and cities: From urban health strategies to the pandemic challenge. a decalogue of public health opportunities. *Acta Biomed.* **2020**, *91*, 13–22, doi:10.23750/abm.v91i2.9515.

4. Tokazhanov, G.; Tleuken, A.; Guney, M.; Turkyilmaz, A. How is COVID-19 Experience Transforming Sustainability Requirements of Residential Buildings ? A Review. *Sustain.* **2020**, *12*, 8732.

5. Tleuken, A.; Tokazhanov, G.; Guney, M.; Turkyilmaz, A.; Karaca, F. Readiness Assessment of Green Building Certification Systems for Residential Buildings during Pandemics. *Sustainability*

2021, *13*, 1–31, doi:https://doi.org/10.3390/su13 020460.

6. Tleuken, A.; Tokazhanov, G.; Serikbay, A.-B.; Zhalgasbayev, K.; Guney, M.; Turkyilmaz, A.; Karaca, F. Household water and energy consumption changes during COVID-19 pandemic lockdowns : Cases of cities of Almaty , Shymkent , and Atyrau ; Kazakhstan. *Buildings* **2021**, *11*, 1–14.

7. Bogler, A.; Packman, A.; Furman, A.; Gross, A.; Kushmaro, A.; Ronen, A.; Dagot, C.; Hill, C.; Vaizel-Ohayon, D.; Morgenroth, E.; et al. Rethinking wastewater risks and monitoring in light of the COVID-19 pandemic. *Nat. Sustain.* **2020**, *3*, 981–990, doi:10.1038/s41893-020-00605-2.

8. Bielecki, S.; Dukat, P.; Skoczkowski, T.; Sobczak, L.; Buchoski, J.; Maciag, Ł. Impact of the lockdown during the covid-19 pandemic on electricity use by residential users. *Energies* **2021**, *14*, 1–32, doi:10.3390/en14040980.

9. Carvalho, M.; Bandeira de Mello Delgado, D.; de Lima, K.M.; de Camargo Cancela, M.; dos Siqueira, C.A.; de Souza, D.L.B. Effects of the COVID-19 pandemic on the Brazilian electricity consumption patterns. *Int. J. Energy Res.* **2021**, *45*, 3358–3364, doi:10.1002/er.5877.

10. Tleuken, A.; Turkyilmaz, A.; Unger, K.; Tokazhanov, G.; El-Thalji, I.; Mostafa, M.Y.; Guney, M.; Karaca, F. Which qualities should built environment possess to ensure satisfaction of higher-education students with remote education during pandemics? *Build. Environ.* **2022**, *207*, 108567, doi:https://doi.org/10.1016/j.buildenv.2021.108567.

11. UNESCO School closures caused by Coronavirus (Covid-19) Available online: https://en.unesco.org/covid19/educationresponse/ (accessed on Jan 20, 2021).

12. Shamsi, M.; Iakovleva, T.; Olsen, E. Employees ' Work-Related Well-Being during COVID-19 Pandemic : An Integrated Perspective of Technology Acceptance Model and JD-R Theory. *Int. J.*

Environ. Res. Public Health **2021**, *18*, 1–22, doi:https://doi.org/10.3390/ijerph182211888.

13. Awada, M.; Lucas, G.; Becerik-Gerber, B.; Roll, S. Working from home during the COVID-19 pandemic: Impact on office worker productivity and work experience. *Work* **2021**, *69*, 1171–1189, doi:10.3233/WOR-210301.

14. Askarov, A. Zhandarbek Bekshin recommended transferring up to 80% of employees to remote work Available online: https://kapital.kz/gosudarstvo/91497/perevesti-na-udalenku-do-80-sotrudnikov-rekomendoval-zhandarbek-bekshin.html (accessed on Oct 27, 2021).

15. Rodzi, N.H. Malaysians struggle with long WFH hours during Covid-19 pandemic Available online: https://www.straitstimes.com/asia/se-asia/malaysians-struggle-with-long-wfh-hours-during-covid-19-pandemic (accessed on Feb 24, 2022).

16. European Comission Working from home across EU regions in 2020 Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210923-1 (accessed on Feb 24, 2022).

17. McCarthy, N. COVID-19: how many remote workers are there in different parts of Europe? Available online: https://www.weforum.org/agenda/2021/05/europeans-work-from-home-remote-covid-coronavirus-pandemic-europe-eu/ (accessed on Feb 24, 2022).

18. Hanadian Nurhayati-Wolff Share of Indonesian population who have been avoiding going to work during COVID-19 outbreak from February 2020 to December 2021 Available online: https://www.statista.com/statistics/1110145/indonesia-avoiding-going-to-work-during-covid-19-outbreak/ (accessed on Feb 24, 2022).

19. Yoon, L. Share of companies allowing employees to work from home due to COVID-19 in South Korea as of August 2020, by industry Available online:

https://www.statista.com/statistics/1103160/south-korea-companies-supporting-work-from-home-by-industry/ (accessed on Feb 24, 2022).

20. STATISTICS ON REMOTE WORKERS THAT WILL SURPRISE YOU (2022) Available online: https://www.apollotechnical.com/statistics-on-remote-workers/.

21. Sas, A. Share of people working remotely from home during the coronavirus (COVID-19) pandemic in Poland in 2020 Available online: https://www.statista.com/statistics/1106996/poland-people-working-remotely-during-covid-19-outbreak/ (accessed on Feb 24, 2022).

22. OECD *Teleworking in the COVID-19 pandemic: Trends and Prospects*; Paris, 2021;

23. Breznik, M.; Lužar, B. *Industrial relations and social dialogue. Spain: working life in the COVID-19 pandemic 2020*; Ljubljana, 2021;

24. Field, M. Working from home is now a corporate weapon to beat coronavirus. Available online: https://www.stuff.co.nz/business/world/119841672/working-from-home-is-now-a-corporate-weapon-to-beat-coronavirus (accessed on Dec 7, 2021).

25. European Union Telework in the EU before and after the COVID-19 : where we were , where we head to. *Sci. Policy Briefs* **2020**, *2009*, 1–8.

26. Fukumura, Y.E.; Schott, J.M.; Lucas, G.M.; Becerik-Gerber, B.; Roll, S.C. Negotiating Time and Space When Working From Home: Experiences During COVID-19. *OTJR Occup. Particip. Heal.* **2021**, *41*, 223–231, doi:10.1177/15394492211033830.

27. Boell, S.K.; Cecez-Kecmanovic, D.; Campbell, J. Telework paradoxes and practices: the importance of the nature of work. *New Technol. Work Employ.* **2016**, *31*, 114–131, doi:https://doi.org/10.1111/ntwe.12063.

28. Shepherd-Banigan, M.; Bell, J.F.; Basu, A.; Booth-LaForce, C.; Harris, J.R. Workplace stress and working from home influence depressive symptoms among employed women with young children. *Int. J. Behav. Med.* 2016, *23*, 102–111.

29. Carnevale, J.B.; Hatak, I. Employee adjustment and well-being in the era of COVID-19: Implications for human resource management. *J. Bus. Res.* **2020**, *116*, 183–187, doi:10.1016/j.jbusres.2020.05.037.

30. Xiao, Y.; Becerik-Gerber, B.; Lucas, G.; Roll, S.C. Impacts of Working from Home during COVID-19 Pandemic on Physical and Mental Well-Being of Office Workstation Users. *J. Occup. Environ. Med.* **2021**, *63*, 181–190, doi:10.1097/JOM.0000000000002097.

31. Pang, Z.; Becerik-Gerber, B.; Hoque, S.; O'Neill, Z.; Pedrielli, G.; Wen, J.; Wu, T. How Work From Home Has Affected the Occupant's Well-Being in the Residential Built Environment: An International Survey Amid the COVID-19 Pandemic. *ASME J. Eng. Sustain. Build. Cities* **2021**, 1–41.

32. Awada, M.; Becerik-Gerber, B.; White, E.; Hoque, S.; O'Neill, Z.; Pedrielli, G.; Wen, J.; Wu, T. Occupant health in buildings: Impact of the COVID-19 pandemic on the opinions of building professionals and implications on research. *Build. Environ.* **2022**, *207*, 108440, doi:10.1016/j.buildenv.2021.108440.

33. Awada, M.; Becerik-Gerber, B.; Lucas, G.; Roll, S.C. Associations Among Home Indoor Environmental Quality Factors and Worker Health while Working from Home during COVID-19 Pandemic. *ASME J. Eng. Sustain. Build. Cities* **2021**, 1–19.

34. Dzhambov, A.M.; Lercher, P.; Browning, M.H.E.M.; Stoyanov, D.; Petrova, N.; Novakov, S.; Dimitrova, D.D. Does greenery experienced indoors and outdoors provide an escape and support

mental health during the COVID-19 quarantine? *Environ. Res.* **2020**, 110420, doi:10.1016/j.envres.2020.110420.

35. Tokazhanov, G.; Tleuken, A.; Durdyev, S.; Otesh, N.; Guney, M.; Turkyilmaz, A.; Karaca, F. Stakeholder based weights of new sustainability indicators providing pandemic resilience for residential buildings. *Sustain. Cities Soc.* **2021**, *75*, 103300, doi:10.1016/j.scs.2021.103300.

36. County Stone Everything you need to know about Lapitec Available online: https://www.countystonegranite.co.uk/blog/inspiration/everything-need-know-lapitec/ (accessed on Sep 24, 2020).

37. Lippe-McGrow, J. The Future of Design After COVID-19 Available online: https://www.departures.com/lifestyle/architecture/architects-predict-future-of-design (accessed on Sep 13, 2020).

38. Pemmada, R.; Zhu, X.; Dash, M.; Zhou, Y.; Ramakrishna, S.; Peng, X.; Thomas, V.; Jain, S.; Sekhar Nanda, H. Science-Based Strategies of Antiviral Coatings with. *Materials (Basel).* **2020**, 1–18.

39. Mukherjee, A.; Babu, S.S.; Ghosh, S. Thinking about water and air to attain Sustainable Development Goals during times of COVID-19 Pandemic. *J. Earth Syst. Sci.* **2020**, *129*, doi:10.1007/s12040-020-01475-0.

40. Brownell, B. Materials and Coatings That Reduce Surface Transmission of Bacteria and Viruses Available online: https://www.architectmagazine.com/technology/materials-and-coatings-that-reduce-surface-transmission-of-bacteria-and-viruses_o (accessed on Sep 19, 2020).

41. Megahed, N.A.; Ghoneim, E.M. Antivirus-built environment: Lessons learned from Covid-19 pandemic. *Sustain. Cities Soc.* **2020**, *61*, 102350, doi:10.1016/j.scs.2020.102350.

42. Domínguez-amarillo, S.; Fernández-agüera, J.; Cesteros-garcía, S.; González-lezcano, R.A. Bad air can also kill: Residential indoor air quality and pollutant exposure risk during the covid-19 crisis. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1–34, doi:10.3390/ijerph17197183.

43. van Doremalen, N.; Bushmaker, T.; Morris, D.H.; Holbrook, M.G.; Gamble, A.; Williamson, B.N.; Tamin, A.; Harcourt, J.L.; Thornburg, N.J.; Gerber, S.I.; et al. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *N. Engl. J. Med.* **2020**, *382*, 1564–1567, doi:10.1056/NEJMc2004973.

44. Wainwright, O. Smart lifts, lonely workers, no towers or tourists: architecture after coronavirus Available online: https://www.theguardian.com/artanddesign/2020/apr/13/smart-lifts-lonely-workers-no-towers-architecture-after-covid-19-coronavirus (accessed on Sep 13, 2020).

45. Stambol Touchless Technology in the Wake of COVID-19 Available online: https://www.stambol.com/2020/05/11/touchless-technology-in-the-wake-of-covid-19/ (accessed on Sep 19, 2020).

46. Spolidoro, B. Healthy Buildings: How Architecture Can Defend Us From COVID-19 Available online: https://www.workdesign.com/2020/05/healthy-buildings-how-architecture-can-defend-us-from-covid-19/ (accessed on Sep 19, 2020).

47. Amerio, A.; Brambilla, A.; Morganti, A.; Aguglia, A.; Bianchi, D.; Santi, F.; Costantini, L.; Odone, A.; Costanza, A.; Signorelli, C.; et al. Covid-19 lockdown: Housing built environment's effects on mental health. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1–10, doi:10.3390/ijerph17165973.

48. ESSA Exercise can help protect your mental health during COVID-19 Available online: https://www.essa.org.au/Public/News_Room/Media_Releases1/2020/Exercise_can_help_protect_y

599 our_mental_health_during_COVID-19.aspx (accessed on Nov 9, 2020).

600 49. Aguilera, A.; Lethiais, V.; Rallet, A.; Proulhac, L. Home-based telework in France: Characteristics,
601 barriers and perspectives. *Transp. Res. Part A Policy Pract.* **2016**, *92*, 1–11,
602 doi:10.1016/j.tra.2016.06.021.

603 50. D'Alessandro, D.; Raffo, M. Adapting the answers to new problems of living in a changing
604 society. *Ann. di Ig. Med. Prev. e di comunità* **2011**, *23*.

605 51. Cuerdo-vilches, T.; Navas-martí, M.Á.; Oteiza, I. A Mixed Approach on Resilience of Spanish
606 Dwellings and Households during COVID-19 Lockdown. *Sustain.* **2020**, *12*, 1–22,
607 doi:10.3390/su122310198.

608 52. Capasso, L.; Gaeta, M.; Appolloni, L.; D'Alessandro, D. Health inequalities and inadequate
609 housing: The case of exceptions to hygienic requirements for dwellings in Italy. *Ann. di Ig.* **2017**,
610 *29*, 323–331, doi:10.7416/ai.2017.2159.

611 53. Bernstein, E.S.; Turban, S. The impact of the 'open' workspace on human collaboration. *Philos.*
612 *Trans. R. Soc. B Biol. Sci.* **2018**, *373*, doi:10.1098/rstb.2017.0239.

613 54. Oldham, E.; Kim, H. IEQ Field Investigation in High-Performance, Urban Elementary Schools.
614 *Atmos.* 2020, *11*.

615 55. Kim, D.H.; Bluyssen, P.M. Clustering of office workers from the OFFICAIR study in The
616 Netherlands based on their self-reported health and comfort. *Build. Environ.* **2020**, *176*, 106860,
617 doi:https://doi.org/10.1016/j.buildenv.2020.106860.

618 56. Raanaas, R.K.; Evensen, K.H.; Rich, D.; Sjøstrøm, G.; Patil, G. Benefits of indoor plants on
619 attention capacity in an office setting. *J. Environ. Psychol.* **2011**, *31*, 99–105,

doi:10.1016/j.jenvp.2010.11.005.

57. Leather, P.; Beale, D.; Sullivan, L. Noise, psychosocial stress and their interaction in the workplace. *J. Environ. Psychol.* **2003**, *23*, 213–222, doi:https://doi.org/10.1016/S0272-4944(02)00082-8.

58. Rohde, L.; Larsen, T.S.; Jensen, R.L.; Larsen, O.K. Framing holistic indoor environment: Definitions of comfort, health and well-being. *Indoor Built Environ.* **2019**, *29*, 1118–1136, doi:10.1177/1420326X19875795.

59. Doling, J.; Arundel, R. The Home as Workplace: A Challenge for Housing Research. *Housing, Theory Soc.* **2020**, *00*, 1–20, doi:10.1080/14036096.2020.1846611.

60. Salamone, F.; Barozzi, B.; Bellazzi, A.; Belussi, L.; Danza, L.; Devitofrancesco, A.; Ghellere, M.; Meroni, I.; Scamoni, F.; Scrosati, C. Working from Home in Italy during COVID-19 Lockdown : A Survey to Assess the Indoor Environmental Quality and Productivity. **2021**.

61. Amick, B.C.; Robertson, M.M.; DeRango, K.; Bazzani, L.; Moore, A.; Rooney, T.; Harrist, R. Effect of Office Ergonomics Intervention on Reducing Musculoskeletal Symptoms. *Spine (Phila. Pa. 1976).* **2003**, *28*, 2706–2711, doi:10.1097/01.BRS.0000099740.87791.F7.

62. Tunay, M.; Melemez, K. An analysis of biomechanical and anthropometric parameters on classroom furniture design. *African J. Biotechnol.* **2008**, *7*, 1081–1086, doi:10.4314/ajb.v7i8.58625.

63. Ruijsbroek, A.; Droomers, M.; Kruize, H.; Van Kempen, E.; Gidlow, C.J.; Hurst, G.; Andrusaityte, S.; Nieuwenhuijsen, M.J.; Maas, J.; Hardyns, W.; et al. Does the health impact of exposure to neighbourhood green space differ between population groups? An explorative study in four European cities. *Int. J. Environ. Res. Public Health* **2017**, *14*, doi:10.3390/ijerph14060618.

64. Wright, A.D. Study: Teleworkers More Productive—Even When Sick Available online: https://www.shrm.org/resourcesandtools/hr-topics/technology/pages/teleworkers-more-productive-even-when-sick.aspx (accessed on Sep 16, 2021).

65. PWC It's time to reimagine where and how work will get done Available online: https://www.pwc.com/us/en/library/covid-19/us-remote-work-survey.html (accessed on Oct 27, 2021).

66. Toscano, F.; Zappalà, S. Social isolation and stress as predictors of productivity perception and remote work satisfaction during the COVID-19 pandemic: The role of concern about the virus in a moderated double mediation. *Sustain.* **2020**, *12*, 1–14, doi:10.3390/su12239804.

67. Monteiro, N.P.; Straume, O.R.; Valente, M. Does Remote Work Improve or Impair Firm Labour Productivity? Longitudinal Evidence from Portugal. *SSRN Electron. J.* **2021**, doi:10.2139/ssrn.3507262.

68. Hadiansah, D.; Sufianty Zafar, T.; Suarsa, A.; Gadzali, S.S.; Rahayu, Y.N. How the Work Environment Affects Employee Competence and its impact on Employee Performance? Survey of the Ministry of Religion of Sukabumi Regency, West Java Province, Indonesia. *Int. J. Emerg. Technol.* **2020**, *11*, 148–151.

69. Djogo, O.; Rudy, E. The Effect of Strategic Economic Management And Leadership Styles On Job Satisfaction And Its Implications On Employee Performance (Survey In Teklom Divre Iii, West Java). *J. Econ. Empower. Strateg.* **2021**, *4*.

70. Ahmad, T.; Thaheem, M.J. Developing a residential building-related social sustainability assessment framework and its implications for BIM. *Sustain. Cities Soc.* **2017**, *28*, 1–15, doi:10.1016/j.scs.2016.08.002.

71. Unachukwu, I.C. Managerial Styles and Employee Performance in Selected Deposit Money Banks in Onitsha. *Int. J. Bus. Manag.* **2020**, *1*.

72. Fu'ad, E.N.; Aminnudin, M. Motivation as An Intervening Variables Influence Competency on the Performance of Cooperative Managers. *J. Manag. Entrep. Res.* **2021**, *1*, doi:10.34001/jmer.2020.12.01.2-11.

73. Mokhtarian, P.L.; Collantes, G.O.; Gertz, C. Telecommuting, Residential Location, and Commute-Distance Traveled: Evidence from State of California Employees. *Environ. Plan. A Econ. Sp.* **2004**, *36*, 1877–1897, doi:10.1068/a36218.

74. Bailey, D.E.; Kurland, N.B. A review of telework research: Findings, new directions, and lessons for the study of modern work. *J. Organ. Behav.* **2002**, *23*, 383–400, doi:10.1002/job.144.

75. Parker, K.; Horowitz, J.M.; Minkin, R. How the Coronavirus Outbreak Has – and Hasn't – Changed the Way Americans Work Available online: https://www.pewresearch.org/social-trends/2020/12/09/how-the-coronavirus-outbreak-has-and-hasnt-changed-the-way-americans-work/ (accessed on Oct 27, 2021).

76. Wang, B.; Liu, Y.; Qian, J.; Parker, S.K. Achieving Effective Remote Working During the COVID-19 Pandemic: A Work Design Perspective. *Appl. Psychol.* **2020**, 10.1111/apps.12290, doi:10.1111/apps.12290.

77. Turkyilmaz, A.; Akman, G.; Ozkan, C.; Pastuszak, Z. Empirical study of public sector employee loyalty and satisfaction. *Ind. Manag. Data Syst.* **2011**, *111*, 675–696, doi:10.1108/02635571111137250.

78. Swarnalatha C.; Sureshkrishna G. Job satisfaction among employees of automotive industries in India. *Int. J. Futur. Comput. Commun.* **2012**, *1*.

79. Girma, S. *The Relationship Between Leadership Style and Employee Job Satisfaction Study of Federal and Addis Ababa Sport Organizational Management Setting in Ethiopia*; Online, 2016; Vol. 8;.

80. Martins, N.; Coetzee, M. Organisational culture, employee satisfaction, perceived leader emotional competency and personality type: An exploratory study in a South African engineering company. *SA J. Hum. Resour. Manag.* **2007**, *5*, 20, doi:10.4102/sajhrm.v5i2.116.

81. Rowe, G.; Wright, G. The Delphi technique as a forecasting tool: issues and analysis. *Int. J. Forecast.* **1999**, *15*, 353–375, doi:https://doi.org/10.1016/S0169-2070(99)00018-7.

82. Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). Thousand Oaks. *Sage* **2013**, 165.

83. Ringle, C.M.; Wende, S.; Becker, J.-M. SmartPLS 3 2015.

84. Cheah, J.-H.; Thurasamy, R.; Memon, M.A.; Chuah, F.; Ting, H. Multigroup Analysis using SmartPLS : Step-by-Step Guidelines for Business Research. **2020**, doi:10.14707/ajbr.200087.

85. Hair, J. *Multivariate Data Analysis: A Global Perspective.*; 7th ed.; Upper Saddle River: Prentice Hall, 2009;

86. Türkyilmaz, A.; Özkan, C. Development of a customer satisfaction index model: An application to the Turkish mobile phone sector. *Ind. Manag. Data Syst.* **2007**, *107*, 672–687, doi:10.1108/02635570710750426.

87. Al-Omari, K.; Okasheh, H. The influence of work environment on job performance: A case study of engineering company in Jordan. *Int. J. Appl. Eng. Res.* **2017**, *12*, 15544–15550.

88. Taba, M.I. Mediating effect of work performance and organizational commitment in the

relationship between reward system and employees' work satisfaction. *J. Manag. Dev.* **2018**, *37*, 65–75, doi:10.1108/JMD-11-2016-0256.

89. University of Exeter Why plants in the office make us more productive Available online: https://www.sciencedaily.com/releases/2014/09/140901090735.htm (accessed on Mar 2, 2022).

90. Ninaus, K.; Diehl, S.; Terlutter, R.; Chan, K.; Huang, A. Benefits and stressors – Perceived effects of ICT use on employee health and work stress: An exploratory study from Austria and Hong Kong. *Int. J. Qual. Stud. Health Well-being* **2015**, *10*, 28838, doi:10.3402/qhw.v10.28838.

91. Ninaus, K.; Diehl, S.; Terlutter, R. Employee perceptions of information and communication technologies in work life, perceived burnout, job satisfaction and the role of work-family balance. *J. Bus. Res.* **2021**, *136*, 652–666, doi:https://doi.org/10.1016/j.jbusres.2021.08.007.