Sustainability **2015**, *7*, 1-x manuscripts; doi:10.3390/su70x000x

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Analysis of Influence of ICT Services Including Network Service and System Integration Service on CO_2 Emission

Tomomi Nagao [1,*], Shinsuke Hannoe [1], Yuiichiro Takei [1], Minako Hara [1] and Jiro Nakamura [2]

[1] NTT Network Technology Laboratories, Tokyo, Japan; E-Mails: nagao.tomomi@lab.ntt.co.jp; hannoe.shinsuke@lab.ntt.co.jp; takei.yuuichirou@lab.ntt.co.jp; hara.minako@lab.ntt.co.jp

[2] NTT Advanced Technology Corporation, Kanagawa, Japan; E-Mail: jiro.nakamura@ntt-at.co.jp

* E-Mail: nagao.tomomi@lab.ntt.co.jp; Tel.: +81-422-59-4540; Fax: +81-422-59-5681.

Academic Editor:

Received: / Accepted: / Published:

Abstract: The use of information and communications technology (ICT) services is expected to reduce the amount of CO_2 emissions. Companies that provide ICT services can argue that their services can help reduce CO_2 emissions. To understand the reduction amount, it is necessary to estimate such reduction through company-wide services. For this study, we developed estimation methods for network services for personal users, network services for corporate users and system integration services. The reduction in CO_2 emissions from the NTT Group in 2013, which was estimated using these methods, has been reported. The reduction in CO_2 emissions due to the use of smartphones in mobile network services is large, and we investigated the cause for this and compared their use with the use of feature phones.

Keywords: ICT; CO_2 emission reduction; estimation method

---

1. Introduction

Nations throughout the world have made efforts to reduce the effects of global warming. The use of information and communications technology (ICT) is expected to be one way of reducing CO_2 emissions with the aim of reducing the effects of global warming [1]. We explain the concept of reducing CO_2 emissions by using ICT of online shopping as an example of ICT services. Online shopping can reduce CO_2 emissions per act of purchase. In such a case, the CO_2 emitted from

transportation is reduced. We can therefore expect that CO_2 emissions will reduced by the use of ICT services.

When estimating the environmental impact of a product or service, the entire life cycle from resource mining to disposal should be considered. This is called life cycle assessment (LCA) and involves calculating the environmental load of the activities involved in each stage of the life cycle of the product or service, such as the consumption of materials and energy and personal travel [2]. The environmental impact assessment of ICT equipment and services should preferably be based on LCA [3]. The reduction in CO_2 emissions is estimated by comparing the environmental impact of ICT equipment and services and conventional means [3]. Conventional means are activities that would be assumed to have the same functionalities as ICT services if ICT had not been introduced. This method is an international recommendation in ITU-T [4].

Businesses that provide ICT services can argue that their services can help reduce the environmental load. Some companies have set targets for reducing CO_2 emissions through the ICT services they provide. Within THE GREEN VISION 2020, the NTT Group has set a target of reducing 20 million tons of CO_2 by 2020 by the use of the services they provide at the customer's own location. To verify how much the target has been met, it is necessary to comprehend how much reduction in CO_2 emissions by using company-wide ICT services.

Malmodin et al. estimated the reduction in CO_2 emissions in company-wide ICT; however, this is an estimation based on the ICT equipment that their company manufactures [5]. There is no mention of the scale of the estimated products in any of the literature, so it is unclear whether the estimation result represents a reduction in the amount of CO_2 emissions across an entire company, except when estimating all ICT equipment. To estimate the reduction in CO_2 emissions for an entire company with a similar method to that of Malmodin et al., it is necessary to estimate all the ICT services of a company. We found that estimation takes one person-month per services from our hearings. Estimating all ICT services of an entire company is difficult from the cost viewpoint. For this study, we developed methods of estimating the reduction for an entire company from the results of estimating individual ICT services.

2. Estimation methods

We investigated a value that is proportional to the reduction in CO_2 emissions and represents the scale of all the services provided by a company (the "scale factor" below). We developed and analyzed methods of estimating the reduction in CO_2 emissions for ICT services over an entire company from data on the reduction in CO_2 emissions of certain individual ICT services.

In consideration of the simplicity of the estimation, we suggested the following in which the scale factor is set to one.

$$Y=aX \tag{1}$$

Y is the sum of the reduction in CO_2 emissions of services provided by a company, a is the CO_2 emissions reduction ratio per unit of the scale factor, and X is the scale factor.

In this study, we selected an X that is proportional to Y and derived an a from the reduction in CO_2 emissions y and scale factor x of individual services. The CO_2 emissions of individual services were estimated based on the Environmental Impact Assessment System [6]. This system is based on LCA. In this case, Y is the sum of y and X is the sum of x. We selected X from published company data that were easy to collect to restrain the operation cost relating to data collection.

When investigating the evaluation method, we divided ICT services into the following categories according to their nature:

(1) Network services for personal users
(2) Network services for corporate users
(3) System integration services

Category (1) refers to broadband network services using PCs or mobile network services using feature phones or smartphones used by individual users. Category (2) refers to network services that are leased-line services or IP-VPN services used by corporate users. Category (3) refers to system integration services for creating systems, including networks to individual corporate users.

2.1. Estimation method for network services for personal users

We first conducted an estimation in 2006 on broadband network services using PCs and on mobile network services using feature phones [7][8][9]. We conducted the estimation again in 2010 [10]. For this current estimation, we made a number of assumptions about the conventional means compared with the estimation of 2006. We also added the estimation of mobile network services using smartphones.

Personal network services can be counted as one contract per user. We obtained the main services used in one contract [11]. Since the average reduction in CO_2 emissions per contract can be calculated, we used the number of contracts as X. In this study, we conducted evaluations on each of the main network services [11], which has a utilization ratio of at least 10% (Table 1). We obtained the conventional means and the corresponding utilization time and rate from a user questionnaire. The user questionnaire was distributed over the Web and involved 1160 people. We obtained the amount of CO_2 emissions per one-year contract of the services being estimated and the corresponding conventional means from the following equation.

$$Cc = L \times Uv \times Uc \times Uu \quad (2)$$

Cc is the amount of CO_2 emissions per year of each service and the corresponding conventional means, L is the unit of emissions, Uv is the utilization amount per single login, Uc is the number of utilizations per year, and Uu is the utilization user ratio.

Table 1. Typical use scenario selection results.

Use Scenario	Mobile Network		Broadband Network
	Feature Phone	Smart Phone	Personal Computer
Voice calls	○	○	○
E-mail	○	○	○

Music (including ring tones)	○	○	○
Images	○	○	○
Games	○	○	○
Entertainment, sports, and news		○	○
Search and link aggregation	○	○	○
Bulletin board		○	○
Personal web site		○	○
Blogs		○	○
SNS		○	○
Free video		○	○
Charged video		○	○
Dining information		○	○
Cell phone manufacturer sites	○	○	
Maps	○	○	○
Transportation info & time schedules	○	○	○
General news	○	○	○
Weather reports	○	○	○
On-line banking		○	○
On-line shopping		○	○
Auctions		○	○
Awards, questionnaires		○	○
Bargains, discount coupons		○	○
Stocks, market information		○	○
Miscellaneous info & culture		○	○

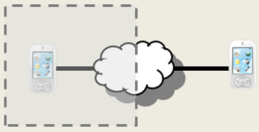
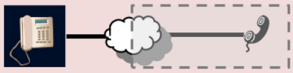
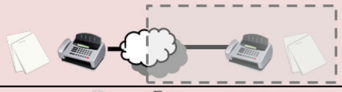
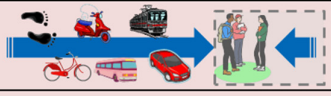
We took the difference between the amount of CO_2 emissions of a service and the amount of CO_2 emissions obtained by conventional means as the reduction in CO_2 emissions per contract for that service. The sum of the services was the reduction in CO_2 emissions for the personal network service. The estimation equation for personal network services is therefore:

$$Y_1=a_1X_1 \quad (3)$$

Y_1 is the reduction in CO_2 emissions, a_1 is the reduction in CO_2 emissions per line, and X_1 is the number of line contracts.

An estimation of CO_2 emissions of email services and conventional means is shown in Fig.1. The figure shown is a concept image. The utilization user ratio of email was obtained from Communications Usage Trend Survey in 2013 and the utilization amount per single login and number of utilizations per year were obtained from a questionnaire [11]. From Equation 2, the amount of CO_2 emissions from email was 0.7 kilograms of CO_2/year. We then selected home phone, public phone, letter, FAX, direct meeting, and nothing as conventional means and obtained the utilization user ratio, utilization amount per single login, and number of utilizations

per year for each from a questionnaire. From Equation 2, the amount of CO_2 emissions from conventional means was 115.7 kilograms of CO_2/year.

		Estimation models	Details(%)	CO_2 emissions (kilograms of CO_2/year)
ICT services	E-mail	 •Smart phone •Mobile network •Data center	100	0.7
Conventional means (for comparison) Without ICT services	Home phone	 •Fixed-line phone •Fixed-line network	58.5	115.7
	Public phone	 •Public phone or round-trip travel •Public phone •Fixed-line network	11.8	
	Letters	 •Letters •Mail or round-trip travel •Mail •Mail out	6.9	
	FAX	 •Paper •Fax machine •Fixed-line network	4.3	
	Direct meeting	 •Round-trip travel	5.5	
	Nothing	 •None	13.0	

 The parts within the broken lines are outside the scope of the evaluation.

Figure 1. Method for calculating the CO_2 emissions reduction for various use scenarios and conventional means (E.g., e-mail).

2.2. Estimation method for network services for corporate users

Corporate network services have usual utilization scenario for each service, and we can assume the type, number, and utilization time for usual utilization equipment, including network circuitry. To make it possible to calculate the average reduction in CO_2 emissions per service contract, we assumed that X was the number of service contracts.

In this study, we considered three types of utilization scenarios from the viewpoint of the number of users (Table 2). The services estimated were IP telephony, teleworking, and groupware. We assumed the type, number, and utilization time for each service and calculated the amounts of CO_2 emissions from them. We also assumed conventional means for each of the services and calculated the amounts of CO_2 emissions from these means. We calculated the reduction in CO_2 emissions per contract of each service from the difference between them and multiplied this by the number of contracts for the service. We took the total of all the services as the reduction in CO_2 emissions for the entire corporate network service. The estimation equation for corporate network services is therefore:

$$Y_2=a_2X_2 \quad (4)$$

Y_2 is the reduction in CO_2 emissions, a_2 is the reduction in CO_2 emissions per contract, and X_2 is the number of service contracts.

Table 2. Services and use scenarios.

	Office-oriented services	Use scenarios		
		Conventional means (before adoption)	⇒	ICT services
1	IP phones	Fixed line and IP line	⇒	integrated to IP
2	Telecommuting	Working at the office (to work, return home)	⇒	Telecommuting (at home, direct return)
3	Groupware	Return to office to check	⇒	Check

2.3. Estimation method for system integration services

The scale of system integration services differs depending on the purpose, type, and scale of the created system. For that reason, it is not possible to calculate the average amount of CO_2 emissions per service contract. We therefore selected X candidates that are proportional to the reduction in CO_2 emissions of the services and selected X that correlated with the reductions in CO_2 emissions using 29 system integration services as samples. During the analysis, we assumed that the mechanism of CO_2 emissions reduction differed with the service from reports by Ugo et al. [12] and Nagao et al. [13]. We divided the services into types and conducted correlation analysis for each type.

We took business data that are open to the general public as X candidates. The business data included sales, equipment, number of employees, etc. Since sales were the data that could be obtained for each individual service, we used sales as X. When classified by customer sector, we were able to confirm a high correlation between the reduction in CO_2 emissions and sales in finance, insurance, public services, and information communications industry (Fig. 2-4). We also verified that this was statistically significant (Table 3). From the above, we took X to be sales of the services for each sector and calculated the reduction in CO_2 emissions by multiplying this by the CO_2 emissions reduction ratio per sale. We calculated the reduction in CO_2 emissions for all system integration services by summing the reduction in CO_2 emissions for each sector being estimated. The estimation equation for system integration services is therefore:

$$Y_3=a_3X_3 \quad (5)$$

Y_3 is the reduction in CO_2 emissions, a_3 is the reduction in CO_2 emissions per unit sales, and X_3 is sales.

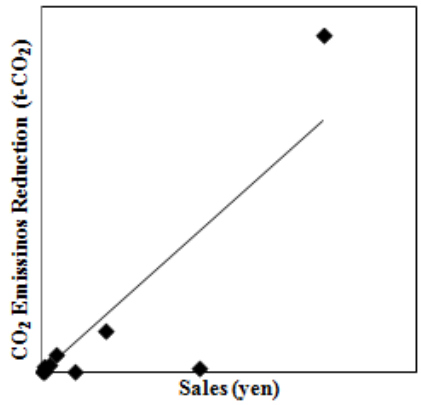


Figure 2. Correlation analysis of "Finance and Insurance" group.

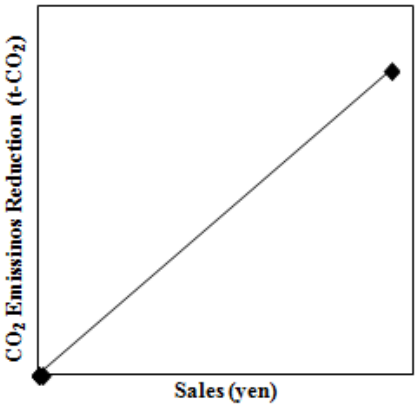


Figure 3. Correlation analysis of "Government" group.

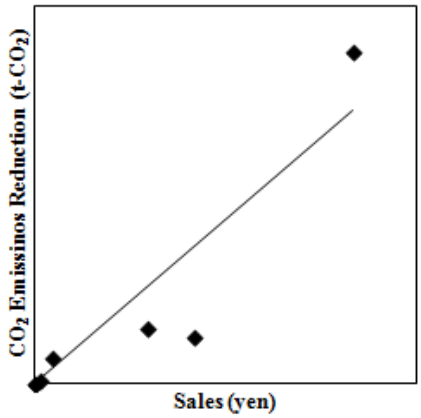


Figure 4. Correlation analysis of "Information and Commnications" group.

Table 3. Results of correlation analysis.

Variable	Finance and Insurance group	Government group	Information and Communications group
R	0.86 (0.00)***	0.99 (0.00)***	0.92 (0.00)***

p-values are reported in parenthesis: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

3. Results and Discussion

The result of estimating the fiscal year 2013 data for the NTT Group using the estimation equations for each category was a reduction in CO_2 emissions of 29.64 million tons for the three categories: network services for personal users, network services for corporate users and system integration services. A comparison with the reduction in CO_2 emissions of 10.37 million tons in fiscal 2010 is given in Fig. 5 [14]. The reduction amount from 2013 had increased by about three times compared with fiscal 2010. However, it is necessary to note that the evaluation ranges were different. Smartphones were newly added to the estimation of personal network services in 2013. Also, new estimation methods were created for estimating corporate network services and system integration services.

A breakdown of the evaluation for fiscal 2013 showed that the reduction in CO_2 emissions was greater in the order of: personal network services, system integration services, and corporate network services. Personal network services accounted for more than half the total, and the effect due to mobile network services was particularly large, due to smartphone use. We considered why the effect on mobile network services by the use of smartphones was larger than when feature phones are used. The CO_2 emissions reduction ratio per number of contracts was 1278.5 kg/(yearly contract) when smartphones were used and 180.1 kg /(yearly contract) when feature phones were used. The main cause of this difference is that the large amount of CO_2 emissions for the conventional means instead of smartphone use. The amount of CO_2 emissions when smartphones were used did not change significantly from when feature phones were used, but there was a significant difference in the amount of CO_2 emissions for each type of conventional means. Since the reduction in CO_2 reduction of each service was calculated by taking the difference between the amounts of CO_2 emissions for the conventional means and for that service, the reduction in CO_2 emissions was larger when the amount of CO_2 emissions for the conventional means is large. One of the reasons the amount of CO_2 emissions for the conventional means of smartphone use is the fact that there are 17 more services to estimate for smartphone utilization than for feature phone utilization. Since the reduction effect is also positive for each service estimated, the effect increased as the number of services increased. The second reason is the fact that the total utilization time of the services was five times longer when smartphones were used than when feature phones were used. To eliminate the differences between the services, we compared 11 services that were common to both types of phones. The total utilization time for the 11 services was three times longer when smartphones were used than when feature phones were used. Another factor is the parameter used in calculating the amount of CO_2 emissions for the conventional means. For example, the emissions of conventional means that involve the movement of people are large, such

as meeting directly instead of using the phone or mail. This means that, if the number of utilizations per year and utilization user ratio is large for these conventional means, the amount of CO_2 emissions can easily be larger than that of other conventional means. In addition, with conventional means involving TV or radio, the amount of information in content for smartphone use is greater than that for feature phone use; therefore, the utilization amount per access is larger.

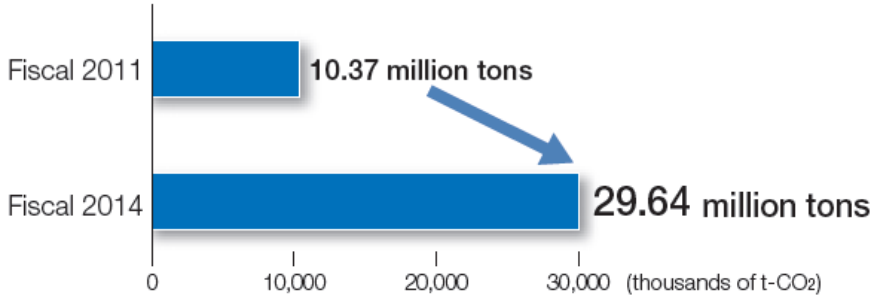


Figure 5. CO2 emissions reduction benefits derived from NTT Group ICT.

4. Conclusions

We developed estimation methods using corporate information to estimate the reduction in CO_2 emissions due to ICT services of an entire company. The estimation method for network services for personal users involves calculating the CO_2 emissions reduction ratio per number of contracts from statistical materials and questionnaires then multiplying that by the number of contracts. The estimation method for network services for corporate users involves calculating this ratio per number of service contracts, assuming average use of main services, then multiplying that by the number of service contracts. The estimation method for system integration services involves calculating this ratio per unit of sales in each industrial sector through statistical analysis using estimation samples of individual services then multiplying that by the number of sales in that industrial field. Using the estimation methods for these three categories, we estimated the reduction in CO_2 emissions of the NTT Group in fiscal 2013. We found that the use of smartphones by individuals greatly affected CO_2 reduction.

Since we expect that new services and terminals will emerge in the future, we will continue to review and estimate services to be estimated. We also set up a study group to estimate the reduction in CO2 emissions of company-level. In study group, we got same results as this paper as based on data of other companies than NTT Group. We can expect that the accuracy of CO_2 emissions reduction ratios from the estimation method for system integration services will increase due to increasing numbers of estimation samples. There is also the possibility of enabling evaluation in industrial sectors where there were few samples and significant results could not be obtained. Also, certain problems should be considered for estimating the environmental impact of ICT [15][16][17]. In this paper, we did not solve all the problems. The baselines were defined as the several conventional means in this paper. But we should review these baselines to fit the era. Differentiating between potential and actual impact and anticipating systemic effects were not solved in this paper. However, we recognize them as important problems, so we currently studying them.

Author Contributions

Nagao.T carried out the studies of estimation method for system integration services and drafted the manuscript. Hannoe.S and Takei.Y carried out the studies of estimation methods for network services. Hara.M participated in the design of the study. Nakamura.J conceived of the study, and participated in its design and coordination.

References and Notes

1. WHITE PAPER 2014 Information and Communications in Japan. Available online: http://www.soumu.go.jp/johotsusintokei/whitepaper/eng/WP2014/chapter-6.pdf (accessed on 25 Sep 2015).
2. ISO 14040:2006. Available online: http://www.iso.org/iso/catalogue_detail?csnumber=37456 (accessed on 25 Sep 2015).
3. The Guideline for Information and Communication Technology (ICT) Eco-Efficiency Estimation. Available online: http://lca-forum.org/environment/forum/past/pdf/10.pdf (accessed on 25 Sep 2015). In Japanese.
4. L.1410: Methodology for environmental life cycle assessment (LCA) of information and communication (ICT) goods, networks and services. Available online: https://www.itu.int/rec/T-REC-L.1410-201412-I/en (accessed on 25 Sep 2015).
5. Malmodin J, Lundén D, Lövehagen N. Methodology for life cycle based assessments of CO_2 reduction potential of ICT services. Sustainable Systems and Technology (ISSST), 2010 IEEE International Symposium, Arlington, VA, 17-19 May 2010; IEEE, the US.
6. Hannoe S, Takei Y, Kitabayashi H. Environmental Impact Assessment System. NTT Technical Review, 2013, Vol. 11, No. 1; NTT, Japan.
7. Sawada T, Origuchi T, Nishi S. Environmental Load Reduction Effects of Ubiquitous Broadband Services. NTT Technical Reivew, 2007, Vol. 5, No. 3; NTT, Japan.
8. Sawada T, Origuchi T, Nishi S, Takahashi I K. Environmental load reduction effect of FTTH and mobile communication services. EcoDesign2006 Asia Pacific Symposium, Tokyo, Japan, 11-12 December 2006; Eco Design Promotion Network, Japan. In Japanese.
9. NTT Group CSR report 2006. Available online: http://www.ntt.co.jp/csreback/2006report/ecology/01.html (accessed on 25 Sep 2015).
10. Ono H, Sakurai A, Nagao T, Tanaka Y, Hannoe S, Kitabayashi H. Environmental Load Reduction Effects of ICT Services. Proceedings of the IEICE Society Conference, Toyama, Japan, 11-14 Sep 2012; the Institute of Electronics, Information and Communication Engineers, Japan. In Japanese.
11. Communications Usage Trend Survey in 2013. Available online: http://www.soumu.go.jp/johotsusintokei/tsusin_riyou/data/eng_tsusin_riyou02_2013.pdf (accessed on 25 Sep 2015).
12. Ugo R. The Environmental Potential of IT for the Ubiquitous-Society. The Journal of the Institute of Electrical Engineers of Japan, 2007, Volume 127 Number 4; The Institute of Electrical Engineers of Japan, Japan; pp. 230-233.
13. Nagao T, Sakurai A, Ono H, Tanaka Y, Hannoe S, Kitabayashi H. Methods for Estimating the Environmental Load Reduction Effects of ICT Services. Proceedings of the IEICE Society

Conference, Toyama, Japan, 11-14 Sep 2012; the Institute of Electronics, Information and Communication Engineers, Japan. In Japanese.

14. NTT Group CSR Report 2014. Available online: http://www.ntt.co.jp/csr_e/2014report/pdf/en_35-39.pdf (accessed on 1 Sep 2015).
15. Hilty M, Aebischer B, Rizzoli E. Modeling and Evaluating the Sustainablity of Smart Solutions. Environmental Modelling and Software, 2014, Vol.56; Elsevier, Netherlands; pp. 1-5.
16. Gossart C. Rebound Effects and ICT: A Review of the Literature. ICT Innovations for Sustainability, 2015, Vol. 310 of the series Advances in Intelligent Systems and Computing; Springer International Publishing, France; pp. 435-448.
17. Townsend J. Web for Sustainability: Tackling Environmental Complexity with Scale. Proceedings of ICT for Sustainability 2014, Stockholm, Sweden, 24-27 Aug 2014; KTH Royal Institute of Technology.