System dynamics approach for investigating a circular economy in the global mobile phone product system

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Introduction

Incremental improvements in the ICT due to rapid innovations have been instigating users to frequently replace their ICT devisees. Thus, the socio-economic activity shortens the life-span of the product, though the technical life-span is longer. As a result, second-hand market of ICT products emerged due to the remaining life of the product. On the other hand, e-waste is increasing as one of the fastest growing waste flows worldwide. In addition, a great interest in e-waste recycling has been shown in developing countries, especially from the informal recycling sector, thanks to several valuable components such as gold in the ICT products. As a result, export of e-waste from industrialized countries to developing countries has increased. These emerging economic patterns not only make the end-of-life of mobile phones complex, but also make the system more challenging to sustainability efforts. Furthermore, the area is characterized by increasing complexity as such and especially in subareas as product design, product manufacturing and distribution, product use and end-of- life systems.

Mobile phone is one of the most important, valuable, hazardous and complex products of ICT. In addition, mobile phones are increasing exponentially for the last 20 years. In this study, we analyze mobile phone product systems. Here, we adopt a dynamic systems modeling approach to the global mobile phone product system. The aim of the study is to identify leverage points for closing the material flow loop and approaching a circular economy.

The objectives of the study are to

- present a conceptual model of a mobile phone product system based on industrial symbiosis,
- implement the conceptual model in a dynamic stocks and flows modeling for the global mobile phone product system,
- identify potential drivers for closing the metal flow loops,
- propose a future optimized scenario by tuning the potential drivers,
- provide suggestions towards a circular economy .

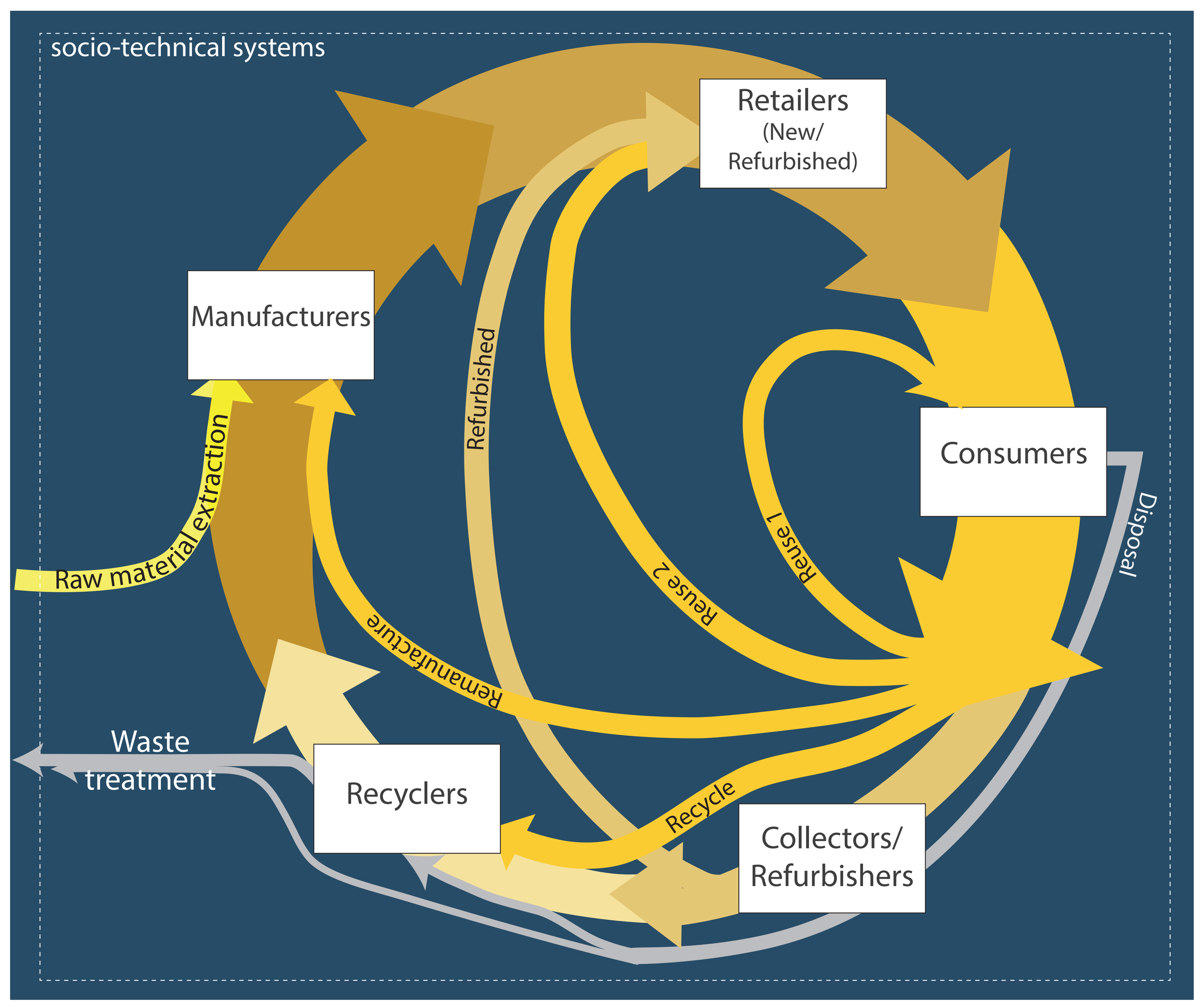

Figure 1: Conceptual model of material flows in a mobile phone product system. The thickness of the flows represents the volume of material qualitatively of a possible industrial symbiosis in the product system.

Methods

We adopt a **system dynamics** (Sterman, 2000) modeling approach to handling the complexity and dynamics of the mobile phone system incorporating socio-economic aspects. In the study, we investigate the drivers through an **element flow analysis** (Cu, Ag, Au, Pd) for closing the material flow loops and approaching a circular economy. Aiming at closing the metal flow loop, this study adopted and modified the system dynamics model demonstrated by Bollinger et al. (2012).

Resource leakage from the system is considered as an indicator of pressure and it is demonstrated by the following two indicators:

Loop leakage determines the resource fraction that is leaving the product system indicating to what extent the loop is closed.

Loop efficiency determines how efficiently the resources are utilized by the system.

Drivers and optimized scenario

A **sensitivity analysis** was conducted to identify the potential drivers. Here, the sensitivity analysis was performed by increasing (or decreasing) one parameter up to 100% keeping other parameters with their default values. Based on the sensitivity analysis, we propose an optimized scenario by tuning the drivers.

Results and discussions

The model outcomes are tested with the field data published in scientific journals. Considering the uncertainty in the field data, the model performance could satisfy for the purposes of this study.

The study finds that the main drivers towards closing the material flows in the system (figure 2) are
(i) accessibility of collection pathways for both industrialized countries (IC) and developing (DC),
(ii) mobile phone use time for both IC and DC,
(iii) gold recovery technology in DC, and
(iv) mobile phone hibernation (e.g., mobile phones under the drawer without any use) for both IC and DC.

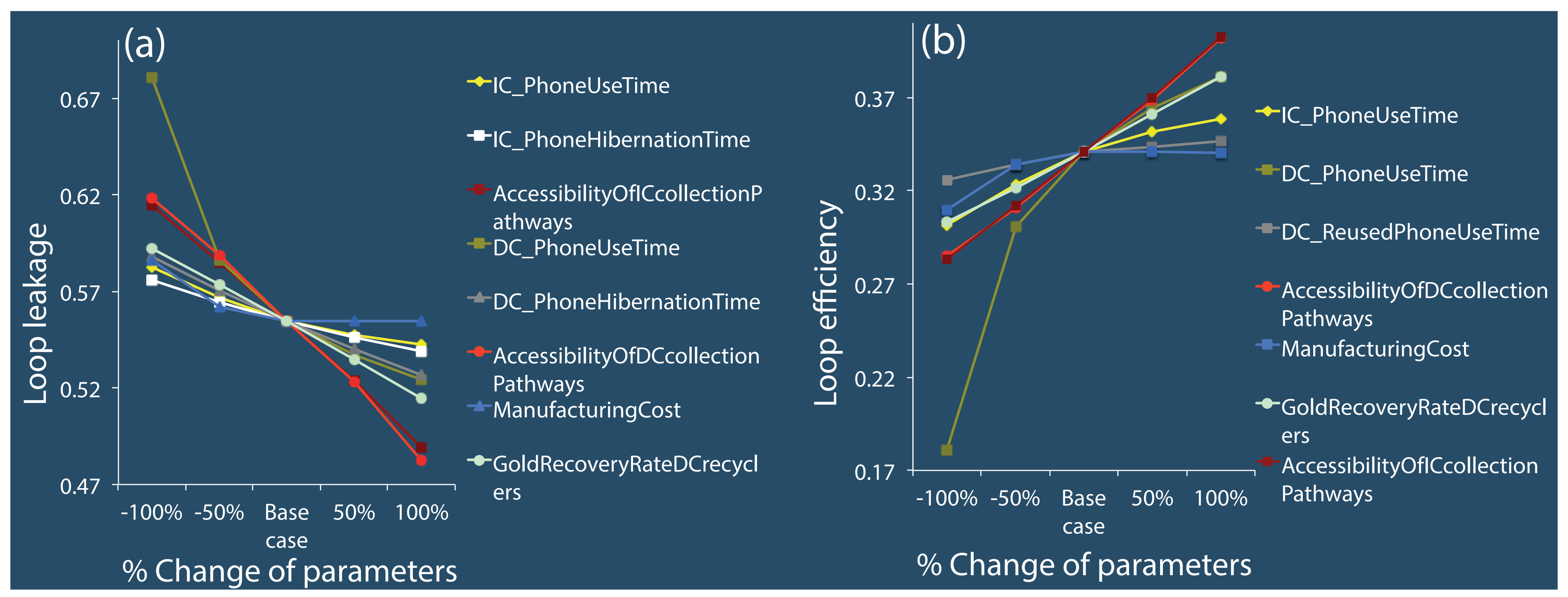

Figure 2: Sensitivity analysis of global (a) loop leakage and (b) loop efficiency in the mobile phone product system with selected parameters used in the model. Base case represents the default parameter settings in the model. IC = Industrialized countries; DC = Developing countries

Surprisingly, other parameters, e.g., manufacturing cost, export cost, utility of a refurbished phone (i.e., functionality compared to a new phone), show a very small contribution in a long term perspective towards closing the loop as well as loop efficiency. These parameters act as stimuli for a very short term in the phone economy.

Parameters (figure 3)	Optimized	Business as usual
new mobile phone use time both for IC and DC	5 years	1.5 years
new mobile phone hibernation both for IC and DC	0.25 years	1 years
accessibility of collection pathways both for IC and DC	100%	50%
consumer awareness both for IC and DC	75%	50%
gold recovery rate of DC recyclers	95%	25%

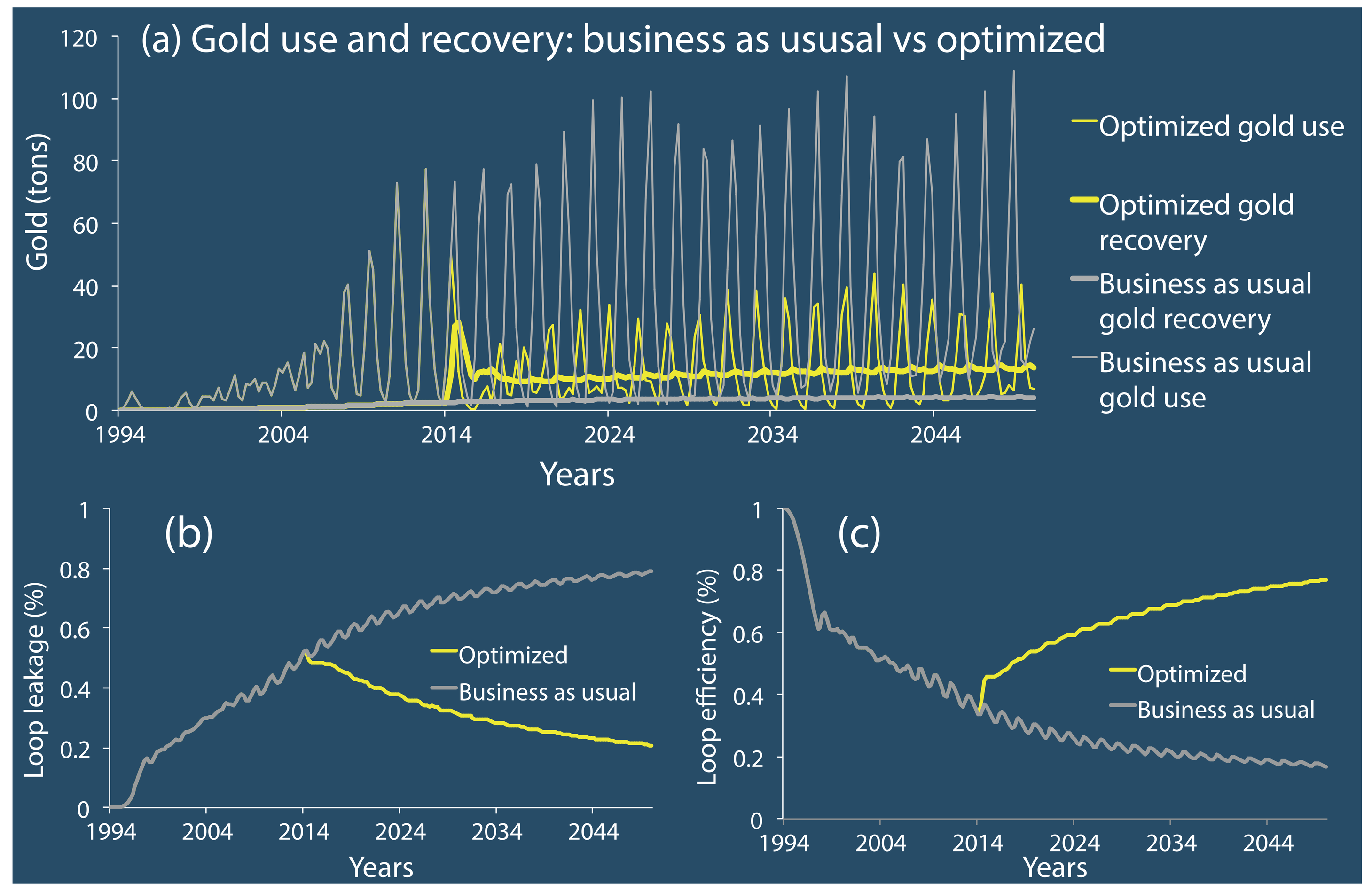

Figure 3: Business as usual and optimized scenarios of (a) gold use for phone productions and gold recovery by recyclers at EoL of phones, (b) loop leakage and (c) loop efficiency.

The proposed optimized model could lessen pressures on resources by decreasing the resource demands for production and increasing resource recovery at the end-of-life of the product (figure 3a), where at business as usual, system leakage is continuously increasing (figure 3b) and resource efficiency is decreasing (figure 3c).

An internalization of external costs, extended producer responsibility, resource platform concept (Ongondo et al., 2013), modular design of phones, improved recycling efficiency could lead the current system towards the proposed optimized scenario. Improved policy support, development of product service systems and introduction of reverse logistics are suggested as important measures towards realizing the findings of this study and fostering a circular economy.

Conclusion

The study investigated the drivers incorporating socio-economic aspects through a systems dynamic approach in an element flow analysis in the global mobile phone product system for closing the metal flow loops. The study found that the current global mobile phone product system is very unsustainable in terms of resource efficiency (approx. 35%) as well as resource leakage (approx. 50%) from the system.

The study finds higher efficiency for closing the loop in collection systems of used phones, mobile phone use time, and informal recycling in developing countries.

By analyzing the dominant parameters, an optimized scenario is proposed which could enhance a closed loop system by decreasing pressures on non-renewable resources. Improved policy supports accompanying consumer and corporate awareness with responsibility could create a circular consumption in the global mobile phone product system.

References

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