Cultural Difference of Customer Equity Drivers on Customer Loyalty: A Cross-National Comparison between South Korea and United States

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ABSTRACT

Purpose: Many advanced discount stores could not reach the certain growth level due to cultural differences and their marketing strategies that have failed to adopt in local market environment. The purpose of this study is to find the effects of customer equity drivers on customer loyalty and to examine cultural differences between South Korea and United States.

Methodology/Approach: This study sets independent variables of value equity, brand equity and relationship equity from the customer equity model and tests to see how each equity driver affects customers' loyalty through gaining their trust and satisfaction in the discount store industry. We applied structural equation model to test the hypothesis. We conducted a survey on customers who had shopping experiences in discount stores and gathered data from United States and South Korea respectively.

Findings: The results show that there are significant differences in the effects of customer drivers on customer loyalty via trust and satisfaction in large retail industries. While Satisfaction had some effects on building their loyalty in Korea, satisfaction had no effect in gaining customers' loyalty in USA.

Research Limitation/implication: The results of this study are highly relevant for managers who must make strategic marketing decisions for different cultures.

Originality/Value of paper: This study is the first systematic cross-cultural examinations on how customer equity drivers in discount stores affect customer loyalty between USA and South Korea.

Category: Research paper

Keywords: cross cultural research; customer equity; trust; loyalty; discount stores

1 INTRODUCTION

Discount retail businesses in Korea have experienced dramatic changes with many multinational corporations entering the market. When retailers enter into other markets, they are advised not to adopt a standardized marketing approach. Because consumers in different countries may have different shopping experiences even in the same type of stores, retailers should consider cultural and environmental differences in local market. For example, Wal-Mart, the biggest discount retail stores in USA, entered South Korea in late 1990s for its international expansion, but failed to survive in this market and left Korea in 2005 as the American way of marketing did not work well in Korea. Of course there were other reasons of Walmart's failures but it is certain that cultural differences existed between Western (USA) and Eastern (Korea) cultures. The customer equity framework (Rust, Lemon and Zeithaml, 2004) suggests that three factors are of particular importance in building a customer base: value equity, brand equity and relationship equity. The model "customer equity drivers" has been researched widely and the similar context have been proposed and tested in many industries such as the European retailing (Vogel, Evanschitzky and Ramaseshan, 2008). But in this model, the influence of cultural differences on perceptions of customer benefits should be considered as critical factors for customer equity drivers. In response, Rust, Lemon and Zeithaml (2004) suggested that it is necessary to empirically validate in what kind of cultures various drivers are more important and less important. We try to find the answer for this suggestion by examining how each equity driver differ on customers' loyalty through gaining their trust and satisfaction in the discount store industry between Eastern (e.g, Korea) and Western (e.g, USA) cultures.

In order to maximize the long-term performance of multinational corporation (MNC), MNC managers should find core factors in specific driver(s) of customer equity and launch suitable programs to enhance it (Ramaseshan, Rabbanee and Tan Hsin Hui, 2013).

Our findings can provide a theoretical framework of the cultural relationships. Moreover, the results can be meaningful for MNC managers who must make strategic marketing decisions from domestic market to a new foreign market.

The remainder of this article is organized as follows: We first present an overview of the theoretical and empirical literature and develops the research hypotheses. We outline procedures to collect and analyse data from two countries, USA and Korea, using statistical methods. Based on the data analysis, we interpret the results to the hypotheses related to the effects of the customer equity drivers on customer loyalty via trust and satisfaction in the discount stores. We then discuss whether the research hypotheses were accepted or not, and offer implications for managers and future researchers.

2 THEORETICAL BACKGROUND

2.1 Cultural Frames that Explain Differences between the USA and Korea

The key for explaining cultural difference in behavioural sciences is to focus on cultural values (Bond and Smith, 1996). Perhaps the best known cultural framework is Hofstede and Hofstede (2001) five-dimensional one: individualism versus collectivism, uncertainty avoidance, long-versus short-term orientation, power distance, and masculinity versus femininity. The first two dimensions are important for consumer behaviour and therefore should be relevant for understanding cross-national cultural difference in customer equity drivers for loyalty intentions.

In Hofstede and Hofstede (2001) cultural dimensions, the USA represents individualism, weak uncertainty avoidance, and short-term orientation, while Korea represents collectivism, strong uncertainty avoidance and long-term orientation. Collectivism is the tendency to place group goals above individual goals. In a collectivist culture, people tend to behave according to the social norms so people more likely to reply on others for their purchase decision and rely on reference groups for making judgments about decision making. whereas people in individualistic cultures value independence and self-sufficiency (Liu and McClure, 2001). Thus, people in an individualistic society are less likely to rely on others (e.g., family members, peers, social groups) in their purchase decisions.

Uncertainty avoidance is defined as ”the degree to which people in a society tolerate ambiguity and uncertainty or feel threatened by ambiguous situations” (Atuahene-Gima and Li, 2002). This concept explains cultural differences in new change by which people prefer stability, predictability, and low stress rather than new experiences. So people with high uncertainty avoidance are less likely to purchase new products (Lowe and Corkindale, 1998) or less-established brands (Bao, Zhou and Su, 2003) and more likely to reply on price as an indicator of quality (Shapiro, 1973).

The USA and Korea are also opposites in Fukuyama’s high-versus low-trust society. According to Fukuyama (1995), culture determines the level of trust that accumulates in the social capital capable of producing economic success. He defines trust as the degree to which people believe others act responsibly and for the common good. He identifies the USA, Japan, and Germany as high-trust societies, while Korea, China and France are low-trust societies.

The authors perceive that such cultural dimensions will have a profound impact on the way consumers perceive and behave, thus influencing the formation of trust and loyalty. Therefore, we propose to measure the effects of customer equity drivers on customer loyalty in large retail stores of two cultural groups-American who are characterized as individualistic and low uncertainty avoidance

and Korean who are characterized as collectivistic and high avoidance in this study.

2.2 Conceptual Framework

There are several studies that conducted research on relationship with customer equity drivers and loyalty intention (Dwivedi, et al., 2012; Vogel, Evanschitzky and Ramaseshan, 2008) as well as in cultural difference that studied (Zhang, Van Doorn and Leeflang, 2014). While, most of these studies essentially focused on B2C context, similar studying has been investigated in a B2B context to find the effects of customer equity drivers on customer loyalty via customer trust (Ramaseshan, Rabbanee and Tan Hsin Hui, 2013). Furthermore, the relationships among loyalty, satisfaction, and trust in retailing contexts have been studied widely and consistent results have been reported. That is, trust-satisfaction (Singh and Sirdeshmukh, 2000), trust-loyalty (Reichheld and Schefter, 2000), and satisfaction-loyalty (Park and Kim, 2003; Yang and Peterson, 2004) links are well established in both online and offline retailing settings in the USA and Korea. So we build the customer equity model of Rust, Lemon and Zeithaml (2004) with combination of trust-satisfaction-loyalty link in large retail store industries to test whether and how the importance of customer equity drivers varies between two countries.

Value equity refers to customer's evaluation of the product based on its utility. Brand equity is a subjective appraisal of customers regarding the brand and is more concerned with its image. Relationship equity involves special relationship bonds that link customers to the company. Trust can be defined as a feeling of security and willingness to depend on someone or something (Chung and Kwon, 2009). Satisfaction is regarded a key outcome of buyer-seller relationships (Anderson, Fornell and Lehmann, 1994). Store satisfaction represents a consumer's overall evaluation of the experience with a specific type of store, that is, a large retail stores like Walmart or Costco. Loyalty is signified by an intention to perform a diverse set of behaviours that signal a motivation to maintain a relationship with the focal firm, engaging in positive word-of-mouth, and repeat purchasing (Sirohi, McLaughlin and Wittink, 1998; Zeithaml, 1988).

3 HYPOTHESE DEVELOPMENT

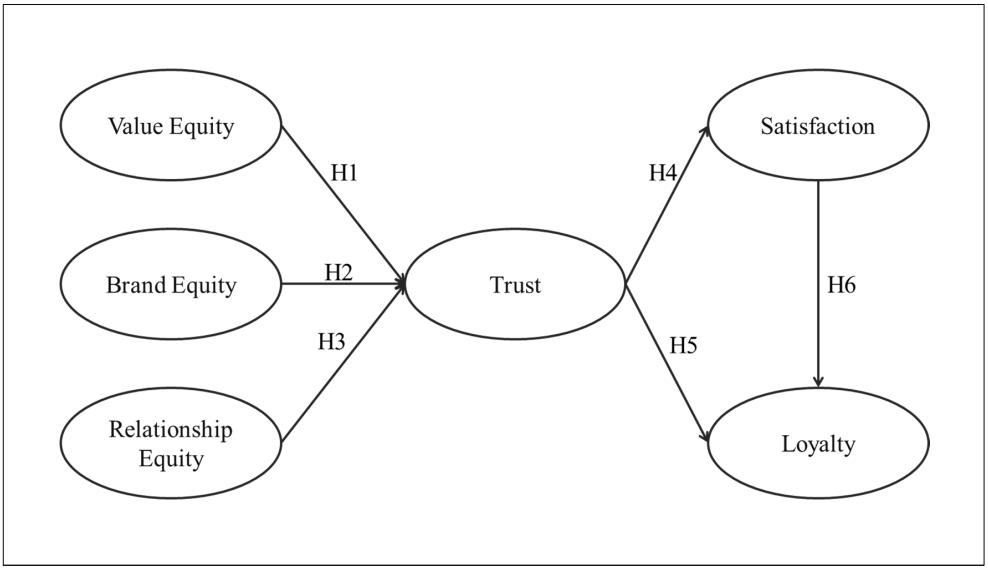

Figure 1 – Research Model

3.1 Value Equity and Trust

Lemon, Rust, and Zeithaml (2001) defined value equity as "customer's objective assessment of the utility of a brand, based on perceptions of what is given up for what is received". It is the perceived ratio between what is received (such as the product and its different benefits) and what is sacrificed (such as the price paid for the product) and thus a higher benefits-cost ratio will yield higher value equity. Value is the keystone of the customer's relationship with the retailers. While judging value of retailers, consumers tend to group pricing, convenience, and quality of product information as aspects of a brand. When a firm delivers such aspects of value equity, it leads to enhanced customer trust and satisfaction and also higher repurchase-intentions (Eggert and Ulaga, 2002). De Mooij and Hofstede (2011) propose that, western consumers adopt a rational decision making style and thus are more price and quality oriented. Brady, Robertson and Cronin (2001) also state that Western consumers care more about the price-quality ratio and previous literature further state that low price and consistent quality affect U.S consumers' loyalty (Lee and Ulgado, 1997). However, Korean consumers possess a lower price consciousness and value for money orientation than U.S consumers. This is probably due to their concerns about face or relationship. These social needs may cause Korean consumers to pay less attention to intrinsic attributes, such as price and quality. Furthermore, Korean consumers in high collectivism cultures, they tend to be influenced by group members and pay attention to others' opinion (Hofstede and Hofstede, 2001). Overall, we expect that due to the influence of face concerns, cultures, and

different decision making style, value equity should have less impact on trust in Korea than United States. So we propose the following hypothesis.

H1: The effect of value equity on trust is higher in United States than in Korea.

3.2 Brand Equity and Trust

Brand equity is a more subjective appraisal of the brand and is more related with abstract image and meaning than the rational factors such as price, quality and convenience (Lemon, Rust and Zeithaml, 2001; Rust, Lemon and Zeithaml, 2004). If customers perceive a particular brand as strong, unique and desirable, they experience high brand equity (Verhoef, Langerak and Donkers, 2007). A brand attaches additional intangible value to products or services compared to non-branded products or services (Vogel, Evanschitzky and Ramaseshan, 2008) and thus attracts customers' trust. Trust in familiar brands enables customers to feel secured and reliable (Delgado-Ballester and Luis Munuera-Alemán, 2001). Previous literature states that brands are especially important in Asia countries (ie Korea) (Henderson, et al., 2003), because brand loyalty enables Korean consumers to keep, save and gain face. Unlike in Western cultures, brand consumption does not merely fulfill material needs but also meets social needs, the preference to be respect by others (Ting-Toomey and Kurogi, 1998). Consumers in a culture of collectivism and high uncertainty avoidance are more likely to form trust via a transference process than are consumers in a culture of individualism and low uncertainty avoidance. The rationale behind this proposition is that in a high uncertainty avoidance culture, where solidarity or tightness is valued, and in a collectivism culture, where strong interpersonal ties and a "we" consciousness prevail, consumers tend to judge others to be similar to themselves. That is, in collectivism and high uncertainty avoidance cultures, trust is more likely to be transferred because individuals tend to judge the target(trust) to be similar to the source (firm reputation). In other words, brand equity is a solid proof source from which trust is determined. As Korea represents collectivism and a high uncertainty avoidance culture, brand equity can be relatively easily transferred to trust (Jin, Yong Park and Kim, 2008)

H2: The effect of brand equity on trust is higher in Korea than in United States.

3.3 Relationship Equity and Trust

Relationship equity involves special relationship elements that link customers to the company and its brand and strengthens these relationships beyond value and brand equity (Richards and Jones, 2008). If the perceived relationship equity is high, customers believe that they are well treated and handled with particular care (Vogel, Evanschitzky and Ramaseshan, 2008). Once customers who visiting large retail stores satisfied with its quality and service, there are more likely to visit the store again, which generate the trust toward the large retail store. The tendency to form long term relationships eventually leads to a state of inertia between buyer and seller which is unwillingness of both parties to bring the

relationship to an end unless something went exceptionally wrong (Gounaris and Venetis, 2002). Many studies report that cultures with high uncertainty avoidance (Korea) resist change and thus are not likely to end valued relationships (Kale and Barnes, 1992). Consumers in a collectivism and high risk aversion (Korea), the relationship between consumers and a retailing brand is more sticker (higher trust) than of individualistic and low risk aversion (USA). Generally, when facing risk-taking decision such as brand switching or taking new experience, their perceived risk with collectivism is higher than that of individualistic cultures (Erdem, Zhao and Valenzuela, 2004). Hence we propose the following hypotheses regarding the effect of relationship equity of trust:

H3: The effect of relationship equity on trust is higher in Korea than in United States.

3.4 Trust and Satisfaction and Trust and Loyalty

One of the characteristics of Hofstede's individualism is trusting of others; individualism promotes a trusting stance; one gets better outcomes assuming that others are reliable. Hence, individualists are much more likely to trust others until they are given some reason not to trust. By contrast, members of collectivism are more likely to base their trust on relationships with first-hand knowledge. That is, they confined themselves to existing in group relationships and withhold trusting others. Due to their emphasis on social relatedness and interdependence, collectivist cultures are sensitive to the in-group-outgroup boundary. (Yamagishi and Yamagishi, 1994). A similar idea is found in Fukuyama's (1995) work. According to Fukuyama (1995), in a low-trust society, such as Korea, members are less likely to trust someone who is not part of their in-group, which deters the creation of corporate organizations that are critical in successful modern economics. Trust also contributes to economic efficiency. A high-trust society allows flexibility and is therefore able to function with fewer regulations and lower transaction costs (Galston, 1996). When trust is exercised a great deal in a society (i.e. USA), it can be hypothesized that the impact of trust on subsequent consumer behaviour (i.e. satisfaction and loyalty) is more direct (without intervening factors) and stronger than in a low-trust society. Therefore, we put the following prediction:

H4: The effect of trust on satisfaction is higher in the United States than in Korea.

H5: The effect of trust on loyalty is higher in the United States than in Korea.

3.5 Satisfaction and Loyalty

It is commonly known that a strong link exists between satisfaction and customer loyalty. Szymanski and Henard's (2001) meta-analysis shows that satisfaction has a positive impact on loyalty. While empirical findings with regard to cultural differences in the satisfaction-loyalty link have not been provided, several studies

propose satisfaction-loyalty link in cultural differences. Liu, Furrer and Sudharshan (2001) found in the bank industry of collectivistic or high uncertainty avoidance cultures (i.e. Korea), consumers tend not to switch or complain even when they receive poor service if they were once satisfied with the service, while in higher individualism or lower uncertainty avoidance cultures (i.e. USA), consumers tend to switch or complain when they receive poor service even if they had high satisfaction during their previous experience. Thus, we put the following hypothesis:

H6: The effect of satisfaction on loyalty is higher in United States than in Korea.

4 RESEARCH METHOD

4.1 Survey Design and Data Collection

We collected data from two countries: Korea and USA, because they are representative of Western and Eastern culture. The original questionnaire was initially developed in English as shown Tab. 1. Then, English questionnaire was translated into Korean by an individual fluent in both English and Korean. The questionnaire was then back-translated into English. We pre-tested both questionnaires to check for the comprehensibility of the instructions, construct, wording and layout in both countries. Respondents were asked to recall a recent visit to their most preferred discount stores. Each item was rated on a five-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5). Information on demographic characteristics and discount store shopping behaviour was also obtained. Respondents were asked about their age, gender and what they shopped at that store.

Table 1 – Measurement Items

Variables	Item	Content	Reference
Value equity	Val1 Val2 Val3 Val4 Val5	Worthwhile High quality and service Proper pricing that matches its quality Easy exchange and refund policy Items are displayed appropriate for shopping	Vogel et al. (2008) Roland et al. (2000)
Brand equity	Br1 Br2 Br3 Br4 Br5 Br6	Have good reputation Innovation Have High ethical standards Remember store's logos or symbols Come up with good images Different from others	Aaker and Equity (1991)
Relationship equity	Rel1	Do services that they don't do for most customers	Hennig-Thurau, Gwinner and Gremler (2002)

Variables	Item	Content	Reference
	Rel2	Send information that is relevant to my purchase	
	Rel3	Seen a large retail store in social network sites	
	Rel4	Participate in the social network communities	
	Rel5	Feel intimacy toward a large retail store	
Trust	Tru1	Believe a large retail store will not try to cheat	Lau and Lee (1999)
	Tru2	Trust a large retail store completely	
	Tru3	Feel secure when use products	
	Tru4	Would make every effort to satisfy me	
Satisfaction	Sa1	Experience in large retail store has been satisfactory	Flavián, Guinalíu and Gurrea (2006)
	Sa2	I am satisfied with the way that the store functions	
	Sa3	Made correct decision to use	
Loyalty	Loy1	I am committed to a large retail store	Zeithaml, Berry and Parasuraman (1996) Quester and Lin Lim (2003)
	Loy2	I say positive things about a large retail store to other	
	Loy3	I recommend the company to anyone who seeks my advice	
	Loy4	I am going to revisit in the future	

A total of 430 responses were collected (Korea: 210; USA: 220). After removing incomplete responses, a total of 198 Korean and 199 American were used to test the proposed model. Participant's demographics are shown in Tab. 2.

Table 2 – Demographic Characteristics of Samples

Classification		USA(n=199)	Korea(n=198)
Gender	Male	127	121
	Female	72	77
Age	10~19	2	2
	20~29	85	127
	30~39	66	50
	40~49	24	4
	50~59 and above	22	15
Population	Big city	33	144
	Middle to small city	87	35
	Rural area	79	19
What to buy	Electronic Appliances	45	1
	Clothing	14	3
	Daily Necessity	77	113
	Fresh Food	57	74
	Etc	6	7
Transportation	By automobile, car	170	46
	By public transportation	18	5
	By walk	11	97

5 RESUTS

5.1 Measurement Item Testing

Data analysis was conducted using the partial least squares (PLS) technique. PLS was chosen because PLS is not as restrictive on the sample as covariance-based structural equation modelling (SEM) methods that require a separate multi-sample analysis for interaction effects along with relatively large sample sizes and multivariate normal data distributions (Jöreskog and Sörbom, 1989).

Table 3 – AVE, CR, and Discriminant Validity of Constructs

	AVE	CR	Cronbach alpha	VAL	BR	REL	TRU	SA	LOY
VAL	0.69(k)	0.82(k)	0.61(k)	**0.83**(k)					
	0.55(u)	0.78(u)	0.62(u)	**0.74**(u)					
BR	0.54(k)	0.82(k)	0.72(k)	0.45(k)	**0.73**(k)				
	0.70(u)	0.87(u)	0.78(u)	0.60(u)	**0.84**(u)				
REL	0.63(k)	0.83(k)	0.70(k)	0.39(k)	0.59(k)	**0.79**(k)			
	0.72(u)	0.83(u)	0.62(u)	0.38(u)	0.52(u)	**0.85**(u)			
TRU	0.66(k)	0.88(k)	0.82(k)	0.45(k)	0.58(k)	0.57(k)	**0.81**(k)		
	0.74(u)	0.92(u)	0.89(u)	0.54(u)	0.65(u)	0.54(u)	**0.86**(u)		
SA	0.66(k)	0.86(k)	0.75(k)	0.47(k)	0.40(k)	0.45(k)	0.62(k)	**0.81**(k)	
	0.80(u)	0.92(u)	0.87(u)	0.58(u)	0.61(u)	0.42(u)	0.54(u)	**0.89**(u)	
LOY	0.67(k)	0.89(k)	0.83(k)	0.42(k)	0.42(k)	0.34(k)	0.57(k)	0.63(k)	**0.83**(k)
	0.82(u)	0.93(u)	0.89(u)	0.21(u)	0.36(u)	0.19(u)	0.33(u)	0.27(u)	**0.91**(u)

Leading diagonal shows the squared root of AVE of each construct.
K: Korea, U: United States.

Before doing multi group comparisons, it is always important to first establish the measures perform adequately in both data samples. To conceptually validate the instrument, we assessed the constructs for convergent and discriminant validity. Convergent validity can be established by examining standardized path loadings of items, composite reliability (CR), Cronbach's alpha, and the average variance extracted (AVE) of constructs (Gefen, Straub and Boudreau, 2000). The standardized path loadings of all items were significant (t-value > 1.96) and

greater than 0.7. Internal reliability for each construct was assessed using Cronbach's alpha. Reliability for all constructs exceeded the suggested level of 0.60 (Nunnally, 1978). This indicates that each of the constructs was adequately captured by its indicators. The CR and AVE for all constructs exceeded 0.7 and 0.5. Thus, each test result met its threshold criterion, and the convergent validity for the constructs was supported.

Discriminant validity of a measurement model is supported when the square root of AVE for each construct is greater than the correlations between that construct and other constructs (Fornell and Larcker, 1981). As shown in Tab. 3, this condition was satisfied.

5.2 Structural Model Testing

We conducted Chin's (2000) multi-group PLS analysis to compare between two group differences (South Korea and USA) which is shown in Fig. 2. It is performed by taking the standard errors for the structural model paths and comparing the equivalent paths across different groups (South Korea and USA in this study) by performing t-tests on their path coefficients.

$$t = \frac{Path_{sample\_1} - Path_{sample\_2}}{\left[\sqrt{\frac{m-1}{(m+n-2)} * S.E._{sample\_2}^{2}}\right] * \left[\sqrt{\frac{1}{m}+\frac{1}{n}}\right]} \quad (1)$$

Where:

$S.E$ is the standard error.

$Path_{sample}$ is the path coefficients in each structural model.

m, n are the sample sizes of dataset.

$(m + n - 2)$ is the degree of freedom.

The significance of the paths was determined using the t-statistical test calculated with the bootstrapping technique (with subsampling of 500). The results of PLS analyses for the Korean and the American models are shown in Fig. 2, Fig. 3, and Tab. 4 respectively.

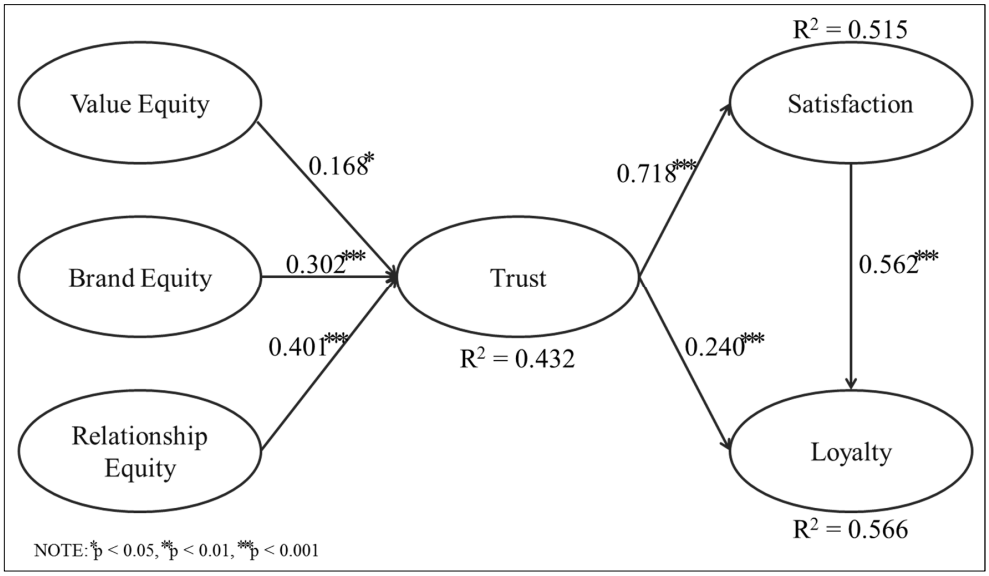

Figure 2 – Results of the Structural Model (KOR)

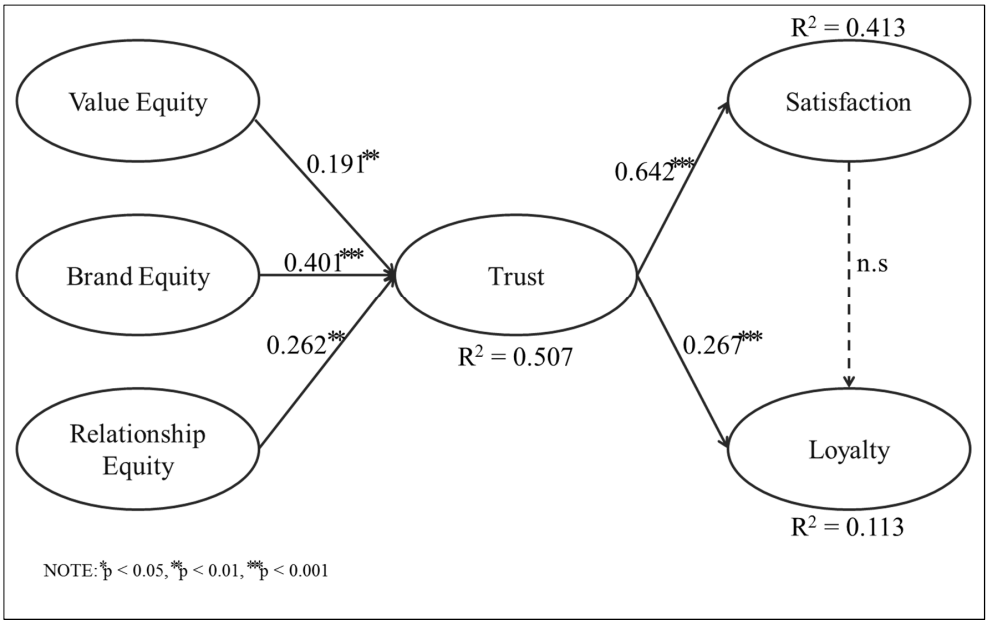

Figure 3 – Results of the Structural Model (USA)

Table 4 – Statistical Comparison of Paths

	Korea(n=198)		United States(n=199)		
Path	Path coefficient	Standard error	Path coefficient	Standard error	Statistical comparison of paths
Value equity → Trust	0.168	0.065	0.191	0.065	3.525***
Brand equity → Trust	0.302	0.076	0.401	0.069	13.590***
Relationship equity → Trust	0.401	0.074	0.262	0.056	21.110***
Trust → Satisfaction	0.718	0.038	0.642	0.042	18.903***
Trust → Loyalty	0.270	0.077	0.247	0.093	3.150**
Satisfaction → Loyalty	0.562	0.075	0.000	0.117	56.944***

Tab. 4 depicts the statistical comparison of paths between the two cultural data sets. The results confirm that there are significant differences in the effect of customer equity drivers on customer loyalty via trust and satisfaction between Korea and USA.

6 CONCLUSION

6.1 Discussion of Findings

We investigated the impact of the three drivers of customer equity on loyalty via trust and satisfaction in two different countries, Korea and USA. The results show that there are significant differences in the effects of customer drivers on customer loyalty via trust and satisfaction in large retail industries. To highlight some of the differences, value equity and brand equity had stronger influence on trust in USA. And relationship equity had a larger effect on trust in Korea. And while Satisfaction had some effects on building their loyalty in Korea, satisfaction had no effect in gaining customers' loyalty in USA. For value equity, this findings consistent with Bao, Zhou and Su (2003) who claim that unlike Asian consumers who are more sensitive in extrinsic variables like brand, country of origin and firm reputation, western consumers have a higher value-for-money orientation and more sensitive in intrinsic attributes such as price and quality. Contrary to our hypotheses, Brand equity has more positive influence on building consumer's trust in USA than in Korea. This result contradicts with previous research findings by Liao and Wang (2009) that Asian consumers would be more brands orientated than Western consumers because of their desire to express social self-worth. It leads to the conclusion that, in Korea, branding seems to be less important for building consumer's trust in retail industries. Furthermore, Relationship equity is found to be more influenced on consumer's trust in Korea than in USA as we expected. This finding is consistent with previous literature that generally Korean consumers care more about the quality

of their interactions with employees such that they may become one of in-group members and get preferential treatments like free gifts or services. However, there is a notable difference in the link between satisfaction and loyalty in two countries. The cross cultural analysis of relationships between satisfaction and loyalty are well established in previous studies and results are generally positive. And our study also shows a positive relationship between satisfaction and loyalty in Korea, but no impact in USA. Normally, once customers are satisfied with products or services, they will have a positive impact on customer loyalty. However, Jones (1996) claims that the link between satisfaction and loyalty is not absolutely positive results. Some prior researchers have found that variety of factors such as product usage, switching costs, consumer knowledge, and sociodemographic (e.g., age, income, and gender) moderate the relationship between satisfaction and loyalty (Homburg and Giering, 2001; Mittal and Kamakura, 2001).The absence of link between satisfaction and loyalty in USA could be explained by cultural differences on our demographic characteristics of samples shown in Tab. 2. It shows the demographic characteristics of the two data sets which are different in terms of age. In Korea, our sample includes mostly from age of 20's and 30's. It may not represent the general population and believe this sociodemographic factor might moderate the relationship between satisfaction and loyalty.

6.2 Implications and Limitations

The customer equity drivers that link with loyalty research has been studied and discussed widely by some scholars. Also, there is a similar research conducting the effect of customer drivers on loyalty via consumer trust in B2B context. But the cross cultural studying of these is still limited. In order to success entry in to the market of other countries, a good strategy of understanding and melt into the host country's culture is very important, particularly for international marketing. Accordingly, we empirically validated and extended existing customer equity model to large retail stores in cross cultural studying by examine of how each customer equity drivers effect on customer loyalty via trust and satisfaction.

Our study offers some important implications for managers. In collectivism cultures such as Korea, Relationship equity shows the most significant impacts on loyalty via trust and satisfaction. So it is more efficient for MNC managers to consider on customer focused marketing to develop on quality relationships with customers. These marketing efforts such as loyalty programs, community-building programs, and special recognition and treatment could enhance consumers' trust and thus increasing consumers' loyalty. In contrast, in more individualistic cultures like USA, value and brand equity are of primary importance in establishing customer loyalty via trust and satisfaction. The importance of value equity depends on the industry, the maturity of the firm, and the customer-decision process, it is important that managers uncover level of influence of various aspects of value on loyalty for different customer segments in their business to that resources can be appropriately allocated, thus

maximizing value equity. MNC managers should choose from several possibilities to strengthen the value perception in the customer's mind, such as offering low prices, improving the quality of assortment, and enhancing store ambience to maximize value equity. Also, MNC managers should focus on brand marketing to build strong and favourable brand image. As there are many competing suppliers in the retail industry, branding is especially important to influence customer perceptions positively and drive store choice generating trust and loyalty. Understanding the changing consumer environment and constantly upgrading the brand to ensure that the brand maintains its level that meets the customer's needs will help managers to enhance brand equity (Vogel, Evanschitzky and Ramaseshan, 2008).

A couple of limitations of this study suggest potential research opportunities. As our Korean sample are limited to ages of 20's to 30's, mostly students and non-marriage workers, these populations may not represent the perceptions of the general population. For future research, a sample should be including more diverse groups of ages to be more representative of the target market of discount stores. As trust is developed thorough various routes and through a dynamic process, diverse aspects of trust need to be accounted for in future research. In addition, ongoing research should verify and extend our model with different countries to determine whether the cultural differences are stable. Also, as customer equity drivers may affect differently according to the market, new areas of markets need to be explored for the future. We used PLS for data analysis and multi-group PLS analysis method (Chin, 2000) is conducted to compare between two group differences. Besides using a PLS technique, AMOS multi group analysis is also known as group comparison tools and it can be used as data analysis and this could be yield different results. Also, it would be interesting to compare the level of significance for the differences in structural paths as provided by AMOS with those from PLS.

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Developing Product Liability Index for Korean Manufacturing Companies

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ABSTRACT

Purpose: PL (product liability) response system is an enterprise-wide system that prevents company's financial loss due to PL-related accidents. This study aims at developing an evaluation system for objectively assessing the extent to which companies carry out systematic and organized activities for product liability, including product safety activities, preventive actions, and protective measures.

Methodology/Approach: We used the Delphi and analytical hierarchy process methods to develop an evaluation system with product liability experts to present the relative importance of response strategy based on selected evaluation criteria. And then, we carried out systematic and organized PL activities of each industry, scale, and growth stage of the Korean manufacturing companies through PLI.

Findings: In terms of the scale of the manufacturer, Large-sized firms has the highest PLI of 92.32. Also, middle- to large sized firms and middle-sized firms have the highest PLI of 90.63 and 77.35, respectively. And then In terms of the importance of all manufacturers, Awareness was identified as the most important component influencing corporate management activities, with the highest PLI of 78.59.

Research Limitation/implication: This study is limited due to the small sample size and the number of examples.

Originality/Value of paper: Our paper will enable consumers to determine a manufacturer's response to product liability, and the subsequent positive effects, such as the increase of quality in consumption life.

Category: Research paper

Keywords: product liability (PL); PL response system; Delphi method; analytical hierarchy process; Korean manufacturing companies

1 INTRODUCTION

Accidents caused by defective products invoke negative response from customers in the market and legal sanctions by the government. A failure to address the initial response will affect the corporate image of the company. The company will have to deal with several other problems along with loss of customers and a decrease in sales. In fact, the Diseases Control Department, under the Ministry of Health and Welfare, carried out an epidemiologic study to investigate the deaths of infants and mothers with diseases due to an unknown virus in 2011. It announced that the use of humidifier disinfectants was very likely responsible for the lung disease with unknown cause. The Diseases Control Department told the citizens not to use humidifier disinfectants and recommended manufacturers and sellers to abstain from selling them.

The causes of humidifier disinfectants incident can be divided into two categories. The first category includes the responsibilities of manufacturers that sold the disinfectants with labels stating that they are harmless to human body because the key raw materials for humidifiers, such as polyhexamethylene guanidine (PHMG), Oligo (2-(2-ethoxy)) ethoxyethyl guanidinium chloride (PGH), are chemicals whose hazards have not been verified. The second category includes a failure to carry out the responsibilities for failing to control the hazardous chemicals. These caused the lung disease and resulted in unprecedented casualties of 142 babies and mothers, and a larger magnitude of deaths. This humidifier disinfectant incident resulted in enormous human damage, including reproach toward the government and deterioration of the corporate image, with damaging reports by the mass media, and deterioration of relationship with victims due to the failure of the company to address the initial response in most cases. However, from the beginning of the incident, both the government and manufacturers should have accurately identified the circumstances that led up to the incident, collected the related information, and acted sincerely (Choi, et al., 2012).

In light of the need for more active measures for improving the safety of supplied products, companies should establish a system to facilitate product safety activities for effectively responding to product liability claims, if any, even after various safety standards and specifications are met. For systematizing product safety activities, companies have to make efforts to build a product liability response system to manage the possible response to any product incident in a systematic manner. In addition, the companies must collaborate with an organization to conduct activities to secure product safety during the product life cycle, from the product development stage to the design, manufacturing, shipment, and disposal of the product (Korean Agency for Technology and Standards, 2015).

It would be better if companies can voluntarily undertake the construction of a response system for product liability, which would be successful in protecting consumers from defective products distributed in the market. However, failure to

protect people from illegal and/or defective products may occur if companies minimize activities to secure product safety and only seek profits, as in the case of people who suffered due to the humidifier disinfectant incident. Accordingly, it is necessary for the government agents to operate a systematic and objective evaluation system, ensure that companies secure product safety continuously, and control their possible response to product accidents. It will help the government in its effort to respond to product accidents in a proper manner, if any, and protect people from defective products distributed in the markets through a product liability response system that is voluntarily implemented by companies.

The study utilized essential components and response strategies of the Product Liability Response System proposed by Seo and Bae (2016) in order to develop a system that can evaluate the operational level of the Product Liability Response System of manufacturing companies.

In order to accomplish the purpose of the study, we conducted a literature survey related to PL and derived operational levels according to the assessment questions and level of responses that were categorized by strategy and evaluation scales (very good, good, moderate, lacking, and very lacking), respectively. In addition, we verified the evaluated items and evaluation ratings by evaluation items through the Delphi method. In addition, AHP method was used to derive the relative importance of response strategies and to calculate the response strategies based on a 100-point scale (Cho, Cho and Kang, 2003; Kim and Choi, 2012; Lee, 2014). Finally, the provision of PLI for each industry, scale, and growth stage of the manufacturing companies through the employment of the evaluation system can help companies understand the operational level of the Product Liability Response System and make up for the product deficiencies. In addition, the consumer can understand the operational level of the Product Liability Response System of the manufacturing company that manufactures the products they purchase. This will help consumers to make further considerations when purchasing the product.

2 BACKGROUND TO PRODUCT LIABILITY RESPONSE SYSTEM

A product liability response system should be constructed considering all the departments of a company during the product life cycle, from the stage of purchasing raw materials, processed items, and parts and materials to production, distribution, after-service, and consumption stages, to respond to any product liability in a systematic manner (Song, 2002; Park, Sung and Kang, 2003, Hong, 2003; Lee and Choi, 2005; Hong, 2010; Kim, Lim and Chung, 2011; Seo, Ko and Bae, 2014; Seo and Bae, 2016). The operation of a product liability response system is the least that a company can do to protect people from illegal and/or defective products. It is an important starting point for companies to recognize their social responsibilities to supply safe products to consumers.

To promote such PLP, PLD, PS strategies in an integrated manner, essential components that either directly or indirectly influence corporate management activities are necessary (Seo, Ko and Bae, 2014; Seo and Bae, 2016). The essential components can be divided into six categories (strategy, organization, training, technology, investment, and awareness) based on literature review and analysis of preceding papers, reports, and research. The roles of these components are as follows. The strategy represents specific response strategy for promoting PL response plans effectively. Organization refers to a corporate response organization that must be established for responding to PL problems effectively. The training represents education and training programs for sufficient understanding among employees to implement the PL measures companywide. The technology represents the technology needed for improving the safety of all products produced by the company in the planning, design, and manufacturing stages, and in identifying the presence of predictable risks. The Investment represents technology securing costs to increase product safety and PL insurance fees to prepare for PL accidents. Lastly, Awareness represents the degree to which participants are aware of PL during all work processes (Song, 2002; Seo, Ko and Bae, 2014; Park, 2014; Seo and Bae, 2016).

Accordingly, manufacturers that have implemented these essential components should operate them systematically for providing a response to possible product accident, if any, although the manufacturers secure product safety from the product designing stage.

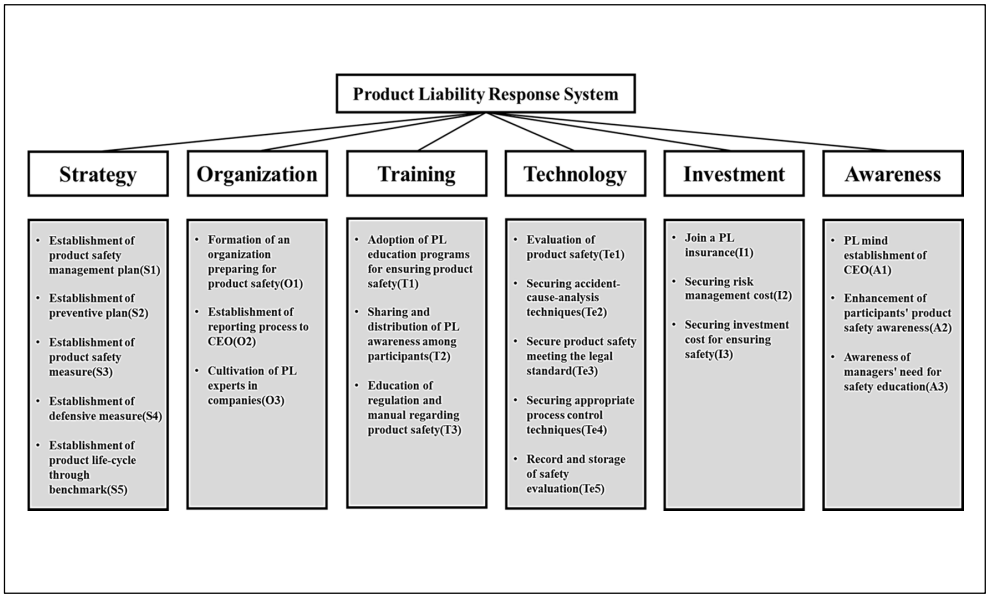

Figure 1 – Product Liability Response System

3 METHODOLOGY FOR DEVELOPING THE PRODUCT LIABILITY INDEX (PLI)

This study aims at developing an evaluation system for objectively assessing the extent to which companies carry out systematic and organized activities for product liability including product safety activities, preventive actions, protective measures, etc. To achieve the purpose of this study, six essential components and 22 response strategies of product liability response system, derived through the preceding study analysis, were used (Seo and Bae, 2016).

We performed this study based on the framework shown in Fig. 2. First, we conducted a literature analysis related to the Product Liability Response System and derived operational levels according to the assessment questions and level of responses categorized by response strategies and evaluation scales (very good, good, moderate, lacking and very lacking), respectively. Subsequently, we conducted an expert survey with PL experts for verifying evaluation scales using the Delphi method. In addition, an AHP method was used to derive the relative importance and priority of essential components and response strategies of product liability response system and to calculate the response strategies based on a 100-point scale. Finally, the evaluation system was extended to derive the Product Liability Index (PLI) for each industry, scale, and growth stage of the manufacturing company.

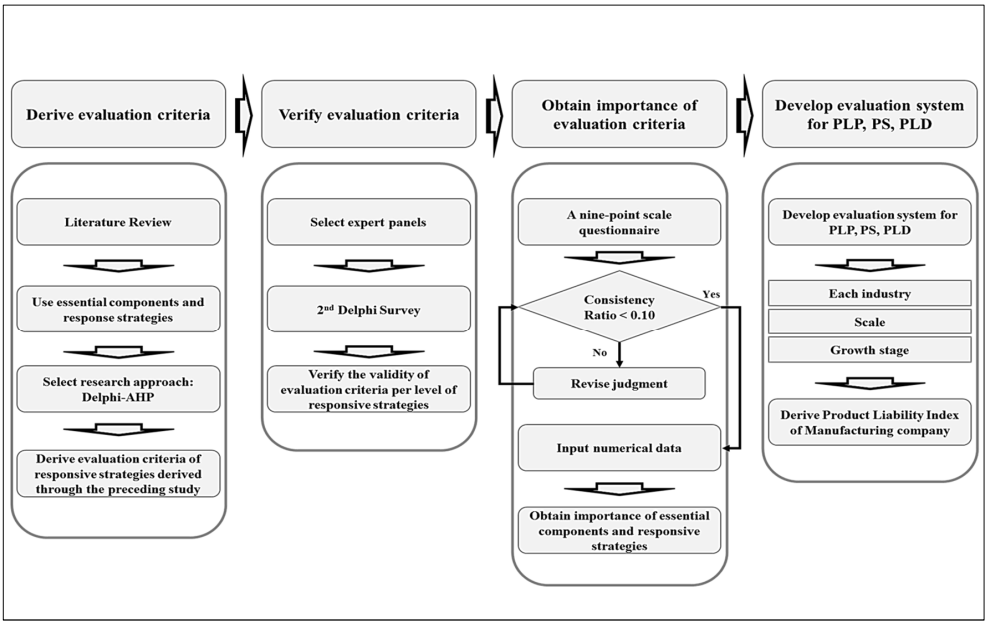

Figure 2 – Development Process of the PLI

3.1 Delphi Method

In this study, we verified the validity of evaluation criteria for 22 response strategies, which were derived through the first questionnaire employed for analysing preceding study. The second questionnaire re-verified the evaluation level of responsive strategies, which were revised from the first questionnaire. The expert panel consisted of 17 voluntary experts, including government officials, researchers, and professors in the field of product liability, chief executive officers, and consultants of manufacturing companies. The participating experts were males aged between 33-57 years, with a mean age of 45.875 years. The work experience of the experts' spanned from 1 year to 27 years, with an average working experience of 14.75 years. Concerning academic qualifications, the panel had four undergraduates, seven master's degree holders, one participant who had completed Ph. D. and five Ph. D. holders. Data collection proceeded with two repetitive surveys from May 1 to June 30 in 2016. The first questionnaire was administered from May 1 to May 31, 2016 and the second questionnaire was administered from June 1 to June 30, 2016.

3.2 AHP Method

In this study, we derived the evaluation points on the evaluation criteria of product liability response index through the questionnaire designed by experts. In the survey, after conducting a pairwise comparison of six essential components, using a scale of nine points, the essential comparison of sub-components was conducted. The study conducted a survey from July 1 to July 30 in 2016 using e-mail and fax targeting experts from CEOs of public organizations, consultant, and academia to evaluate the importance of the six essential components of companywide PL response system derived through preceding study analysis. From the collected questionnaires, the combined geometric mean of all values was calculated. These values were evaluated by each component and by every expert in the pairwise comparison matrix that was composed by the experts using the AHP.

4 VERIFYINICATIG EVALUATION CRITERIA OF THE PLI

We verified the reliability and validity of the evaluation criteria per responsive strategy derived through the preceding studies. The questionnaire comprised partially open-ended questions that aimed to facilitate the derivation and verification of the response level per responsive strategy of a manufacturer under five evaluation scales, such as very good, good, moderate, lacking, and very lacking.

Opinions suggested by the panel can be summarized as follows:

- *Expert 1: The modification of the evaluation criteria is necessary so that the evaluator can make evaluations objectively.*
- *Expert 2: Responsive Strategy No. 2, 8, 10, 11, 12, 13, 14, 15, 16, 20, 21, and 22 need modification.*
- *Expert 3: It is necessary to enter items related to the characteristics of the applicable company in order to make an objective evaluation system in future.*
- *Expert 4: Responsive Strategy No. 1, 2, 3, 4, 5, 6, 7, 16, and 22 need modification.*

Through the second questionnaire, the evaluation criteria in Tab. 1 was developed using 22 responsive strategies for conducting a possible objective evaluation on the response level per responsive strategy for the product liability of a manufacturer.

Table 1 – Evaluation Criteria in the PLI

Evaluation criteria
1. S1. As for the business policies on product safety suggested below, how many policies has your company established?
2. S2. Does your company have a system that establishes rational prevention measures in preparation for PL?
3. S3. Has your company established rational measures on product safety as well as appropriate, relevant details to prepare for PL?
4. S4. Has your company appropriately established defensive measures as well as relevant details in order to minimize corporate loss?
5. S5. Has your company set appropriate confrontational strategies on product life cycle by benchmarking other companies?
6. O1. Has your company established an appropriate organization to prepare PL?
7. O2. Has your company formulated an appropriate reporting system to the CEO to swiftly respond to the claims on PL?
8. O3. Has your company established an appropriate training system to foster in-house PL experts?
9. T1. Has your company established an appropriate training program on PL, which targets corporate members to ensure product safety?
10. T2. Has your company set an appropriate system for enhancing the awareness of corporate members of PL and exchanging PL-related ideas?
11. T3. Has your company established an appropriate training system on the policies and manuals related to product safety?
12. Te1. Has your company formulated a system for evaluating the safety of products manufactured by your company from product design to production?

Evaluation criteria
13. Te2. Does your company ensure technologies and manpower system to analyze the causes of faults generated in the products manufactured by your company?
14. Te3. Has your company set the procedure that satisfies legal standards on the safety of products manufactured by your company?
15. Te4. Has your company established a system that ensures process management technology to satisfy the requirements of product design?
16. Te5. Has your company established a system for recording and storing details (i.e. manufacturing process, quality management, quality inspection, and repair records) on reviewing product safety?
17. I1. Has your company registered for the PL insurance to prepare for the accidents related to PL?
18. I2. Does your company ensure risk management cost to prepare for the accidents related to PL?
19. I3. Does your company ensure financial investment cost to fulfill product safety and prepare for PL?
20. A1. Is the CEO of your company aware of the importance of PL law?
21. A2. Are the entire managers of your company fully aware of the need for safety training?
22. A3. Are the entire members of your company fully aware of the details on PL as well as product safety?

5 DETERMINING PRIORITIES OF PLI EVALUATION CRITERIA

To derive the evaluation grade on the evaluation criteria of the PLI, the evaluated points on essential components and responsive strategies were derived on the basis of 100 points (full score), in consideration of the relative importance and weight of essential components and responsive strategies derived through the AHP method. For this purpose, it was important for the evaluator to provide consistent responses and to ensure the usage of a consistency ratio. Consistency measures the logical inconsistencies of the evaluator's judgment; the degree of consistency is said to be consistent if the consistency ratio does not exceed 0.1.

Tab. 2 shows the relative importance results for essential components of the PLI. In terms of the importance of each essential component of the PLI, *Technology* is identified as the most important component with a weight of 0.247, which was followed by *Awareness* at 0.213, *Strategy* at 0.158, *Investment* at 0.169, *Training* at 0.113, and *Organization* at 0.100, in descending order. Subsequently, the total points per essential components are shown in Tab. 2, where *Strategy*, *Organization*, *Training*, *Technology*, *Investment*, and *Awareness* have 15.8, 10.0, 11.3, 24.7, 16.9, and 21.3 points, respectively.

Table 2 – Essential Components and Response Strategies in the PLI

Components	Relative weights using AHP	Modification	Percentiles
Strategy	0.158	0.158×100	15.8
Organization	0.100	0.100×100	10.0
Training	0.113	0.113×100	11.3
Technology	0.247	0.247×100	24.7
Investment	0.169	0.169×100	16.9
Awareness	0.213	0.213×100	21.3

In the next stage, the evaluation grade of responsive strategies were derived in consideration of total points in the area of essential components, which appeared in Tab. 3, to derive the evaluation points of responsive strategies per essential components. Tab. 3 shows the evaluation points of 22 responsive strategies were derived based on 100.00 points in total (Lee, 2014).

Table 3 – Evaluation Grade of Response Strategy in the PLI

Response Strategy	Local Weights	Modification	Percentiles
Establishment of product safety management plan (S1)	0.245	0.245×15.8	3.87
Establishment of preventive plan (S2)	0.203	0.203×15.8	3.21
Establishment of product safety measure (S3)	0.277	0.277×15.8	4.38
Establishment of defensive measure (S4)	0.129	0.129×15.8	2.04
Establishment of product life cycle through benchmark (S5)	0.146	0.146×15.8	2.31
Total	**1.00**		**15.80**
Organizational maintenance on product safety (O1)	0.380	0.380×10.0	3.80
Establishment of reporting process to CEO (O2)	0.238	0.238×10.0	2.38
Cultivation of PL experts in companies (O3)	0.382	0.382×10.0	3.82
Total	**1.000**		**10.00**
Adoption of PL education programs for ensuring product safety (T1)	0.299	0.299×11.3	3.38
Sharing and distribution of PL awareness among participants (T2)	0.236	0.236×11.3	2.67
Education on product safety regulation and manual (T3)	0.466	0.466×11.3	5.27
Total	**1.00**		**11.31**
Evaluation of product safety (Te1)	0.177	0.177×24.7	4.37
Securing accident-cause-analysis techniques (Te2)	0.131	0.131×24.7	3.24
Secure product safety by meeting the legal standards (Te3)	0.282	0.282×24.7	6.97
Securing appropriate process control techniques (Te4)	0.290	0.290×24.7	7.16

Response Strategy	Local Weights	Modification	Percentiles
Record and storage of safety evaluation (Te5)	0.120	0.120×24.7	2.96
Total	**1.00**		**24.70**
Join a PL insurance (I1)	0.419	0.419×16.9	7.08
Securing risk management cost (I2)	0.253	0.253×16.9	4.28
Securing investment cost for ensuring safety (I3)	0.328	0.328×16.9	5.54
Total	**1.00**		**16.90**
PL mind establishment of CEO (A1)	0.542	0.542×21.3	11.54
Enhancement of participants' product safety awareness (A2)	0.256	0.256×21.3	5.45
Awareness of managers' need for safety education (A3)	0.202	0.202×21.3	4.30
Total	**1.00**		**21.30**

Tab. 4 shows the derived results of evaluation grade per scale as well as evaluation criteria of the PLI using the evaluation points of essential components and responsive strategies. Considering the derived method, the weight for the points of 22 responsive strategies was given to the level of 80% (Good), 60% (Moderate), 40% (Lacking), and 20% (Very Lacking) after the full score of 100 points were allocated to the level of excellence (Very Good).

Table 4 – Evaluation Grade of Evaluation Criteria in the PLI

Evaluation criteria	Evaluation Grade				
	Very Good	Good	Moderate	Lacking	Very Lacking
S1	3.87	3.10	2.32	1.55	0.77
S2	3.21	2.57	1.93	1.28	0.64
S3	4.38	3.50	2.63	1.75	0.88
S4	2.04	1.63	1.22	0.82	0.41
S5	2.31	1.85	1.39	0.92	0.46
O1	3.8	3.04	2.28	1.52	0.76
O2	2.38	1.90	1.43	0.95	0.48
O3	3.82	3.06	2.29	1.53	0.76
T1	3.38	2.70	2.03	1.35	0.68
T2	2.67	2.14	1.60	1.07	0.53
T3	5.27	4.22	3.16	2.11	1.05
Te1	4.37	3.50	2.62	1.75	0.87
Te2	3.24	2.59	1.94	1.30	0.65
Te3	6.97	5.58	4.18	2.79	1.39
Te4	7.16	5.73	4.30	2.86	1.43

Evaluation criteria	Evaluation Grade				
	Very Good	Good	Moderate	Lacking	Very Lacking
Te5	2.96	2.37	1.78	1.18	0.59
I1	7.08	5.66	4.25	2.83	1.42
I2	4.28	3.42	2.57	1.71	0.86
I3	5.54	4.43	3.32	2.22	1.11
A1	11.54	9.23	6.92	4.62	2.31
A2	5.45	4.36	3.27	2.18	1.09
A3	4.3	3.44	2.58	1.72	0.86
Total	**100.00**	**80.00**	**60.00**	**40.00**	**20.00**

6 ANALYSIS OF KOREAN MANUFACTURING COMPANY'S PLI

This study used a system that evaluates the level of response to PL to classify and analyse 40 manufacturers according to the industry, size, and growth stage. The industries to which the manufacturers belonged are classified into rubber and plastic product manufacturing; metal processing, product manufacturing; other machine and equipment manufacturing; other product manufacturing; food manufacturing; medical substance and supply manufacturing; high-precision medical, optical instrument and clock manufacturing; vehicle and trailer manufacturing; electrical device manufacturing; electronic part, computer, video, sound, and telecommunication device manufacturing; and chemical substance and product manufacturing. In terms of the size, the firms are classified into large firms, middle- to large-size firms, middle-size firms, and small-size firms. The growth stages of firms are classified into the stages of decline growth, rapid growth, survival growth, start-up growth, and development growth. The data were obtained based on the representatives of manufacturing firms or quality managers through direct visit, interviews, or telephonic conversation from October 24 to November 11, 2016. Each question in the questionnaire was coded and analysed in the Microsoft Excel.

Tab. 5 shows the result of examining the PLI based on all the manufacturers that participated in the survey. The PLI of manufacturers that participated in the survey is analysed to be 75.41. Specifically, the PLI is 11.31, 7.71, 7.93, 19.31, 12.42, and 16.74 for strategy, organization, training, technology, investment, and awareness, respectively. Concerning the percentage of PLI based on each factor, training and technology have the lowest PLI at 70.18% and 78.18%, respectively, and awareness has the highest PLI at 78.59%.

This result indicates that the manufacturers have established strategies that encourage all the corporate members to recognize and understand corporate

policies fully in order to form response strategies that are different from those of other firms based on the technical skills that ensure product safety and quality.

Table 5 – PLI by Korean Manufacturing Company's

Components	*Str*	*Org*	*Tra*	*Tech*	*Invest*	*Awa*	Total
Value	11.31	7.71	7.93	19.31	12.42	16.74	75.41
Full Marks	15.8	10.0	11.3	24.7	16.9	21.3	100.00
Value/Full Marks	71.58%	77.10%	70.18%	78.18%	73.49%	78.59%	75.41%

6.1 PLI Analysis Results by Industry Sector

The result of examining the PLI based on the industries shows that the index is the highest at 96.45 out of 100 in other machine and equipment manufacturing industries, followed by 90.23, 82.68, 79.99, 77.58, 76.32, 73.42, 67.86, 66.73, 65.45, and 59.89 in industries manufacturing food products, rubber and plastic products, chemical substance and products, vehicles and trailers, electronic components, high-precision medical and optical instruments, other products, electrical equipment, metal processing products, and medical substances and supply, respectively.

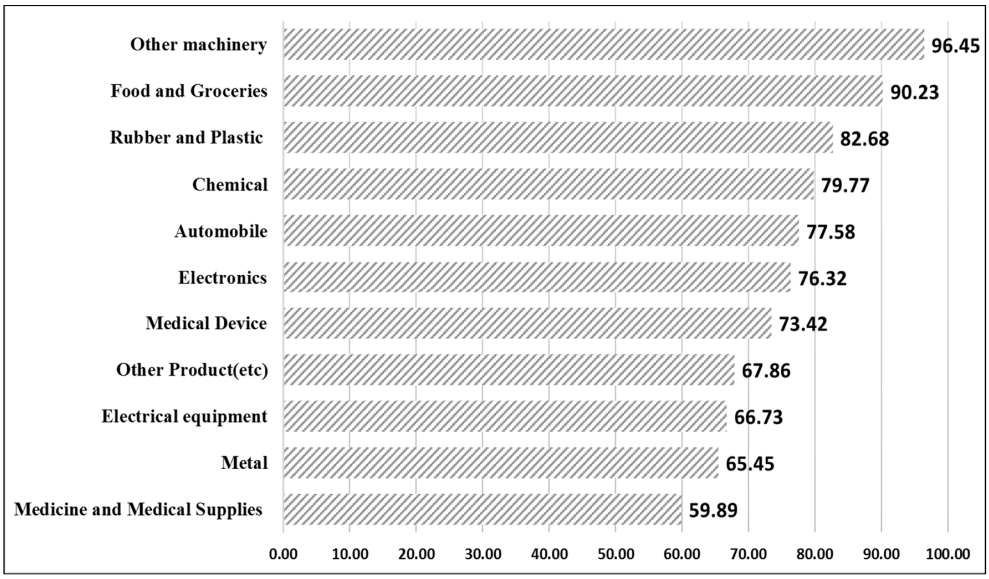

Figure 3 – PLI by the Industry Sector

This result indicates that manufacturers in the industries related to food, chemicals, electronic appliances, and vehicles carry out product safety measures. It can minimize the product-related accidents in all the stages of product planning, design, and production more systematically in these industries than

those in other industries in that the provision for compensating for damages to persons injured by unsafe products would be extended by the former industries than by the latter more in the former industries than in the latter industries.

6.2 PLI Analysis Result by Corporate Scale

The result of examining the PLI according to the corporate scale shows that the index is the highest at 92.32 out of 100 for large-sized firms, followed by 90.63, 77.35, and 63.03 for middle- to large-sized firms, middle-sized firms, and 63.03 small-sized firms, respectively.

This result verifies that large-sized firms can carry out safety management more systematically than small- to middle-sized firms based on their abundant funding, technology, work force, systems, and other fields related to product liability. As the small- to middle-sized firms are exposed to inadequate environments compared to large-sized firms, they should establish response strategies for conducting PL based on strategic prioritization of limited resources throughout the enterprise and encourage the active participation of CEOs. In addition, they should perform education and training for employees to increase their awareness on the importance of PL and execute response strategies for fostering in-house PL experts.

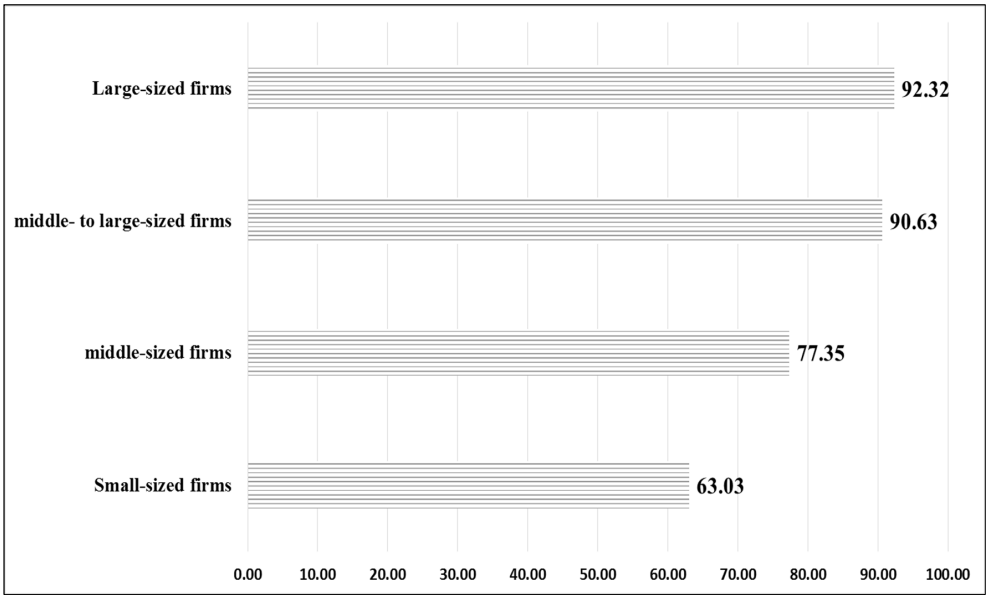

Figure 4 – PLI by Corporate Scale

6.3 PLI Analysis Results by Stages of Corporate Growth

The result of examining the PLI according to the stages of corporate growth shows that the index is the highest of 77.67 out of 100 for the firms in the rapid growth stage, followed by 77.24 for those in the stage of survival, 73.95 for those in the stage of development, 70.41 for those in the stage of start-up, and 52.54 for those in the stage of decline. This result is derived because firms in the stage of high growth take the lead in industrial and technical standards when they release new products and establish PL response strategies by reviewing the potential safety problems of products to ensure competitiveness in the market.

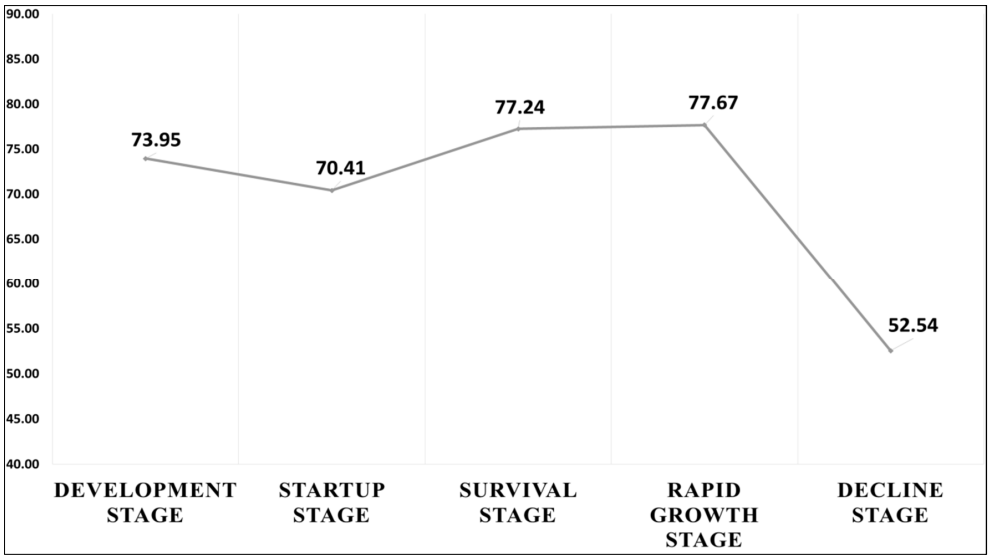

Figure 5 – PLI by Corporate Growth Stage

7 CONCLUSIONS

It is beneficial for companies to protect consumers from defective products distributed in the markets through voluntary management activities. Moreover, incidents may reoccur with a greater impact on the safety and life of people, if the companies solely seek profits over activities that secure product safety, as shown in the humidifier disinfectant incident. Therefore, it is necessary to introduce a certification system for conducting objective evaluation to ensure that the safety of products manufactured by companies can be voluntarily secured with a reasonable response to product accidents, if any.

This study has developed the evaluation standards and scoring system based on evaluation standards, which can objectively assess the PL activities of manufacturers, by analysing previous studies on PL and using the Delphi and AHP methods that can collect the individual opinions and insight of many experts. Moreover, it has identified the level of manufacturers according to the

industries, size, and growth stages by practically applying the PL response level evaluation system in order to provide base data that can be used to constantly increase the quality of products manufactured by these firms.

Study results can be briefly summarized as follows. The PLI of manufacturers that participated in the survey is found to be 75 out of 100, thus indicating that these firms mainly carry out strategies for applying technology that can ensure safety and quality from the stage of product design and helping corporate members to fully recognize the importance of PL. In terms of the industries, manufacturers in the industries where PL accidents occur frequently and liability for damages is great conduct PL activities more systematically. As for the scale of firms, large-size firms that ensure more abundant funding, technology, and manpower perform more systematic activities than small- to middle-size firms that are exposed to inadequate environments. Finally, Rapid growth firms that take the lead in the market execute response strategies that ensure product competitiveness and quality more constantly than firms in the stages of start-up and decline.

Through the findings of this study, manufacturers may effectively secure product safety in constant collaboration with an organization that has a system for providing reasonable responses to possible product accidents. In addition, the study provides information with which consumers can identify the product liability response level of a manufacturer. In addition, the study highlights the positive effects of product liability response, such as maintaining quality throughout the product life cycle

However, this study is limited by its sample size and only a few companies were surveyed due to limited budget and time. Thus, it is hoped that further research will be conducted with more data, thereby supplementing the limitations of this study.

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Retailer's Innovative Differentiation Method Based on Customer Experience: Focusing Mediating Effect of Omni-channel Shopper Type

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ABSTRACT

Purpose: The purpose of this study is to examine the relationship between customer satisfaction and customer attitude by focusing on the mediating effect of Omni-channel shopper type.

Methodology/Approach: A survey questionnaire was conducted by the consumer who purchased fashion clothing at SPA brand store in Daegu, Korea. Total of 364 survey responses were collected for data analysis.

Findings: The study found that customer experience has been stimulated by experiential providers. It was also found that customer experience positively influenced on store attitude.

Research Limitation/implication: This study limited the retail stores to SPA brand stores. Therefore, there had limitation in generalizing the results of this study in other types of retail industry.

Originality/Value of paper: The study will be of benefit to both the scholars and marketing practitioners in terms of moderating effect of Omni-channel shopper types on consumer satisfaction.

Category: Research paper

Keywords: experiential providers; customer experiences; store attitudes; customer satisfaction; Omni-channel shopper

1 INTRODUCTION

Customer experience is an abstract concept. It is the collection of processes that companies use to track every interaction between customers and the organizations throughout the customer lifecycle. Organizations are trying to

optimize interactions from the customer's perspective to obtain and enhance customer loyalty. To manage customer experience, companies need to develop a strategy that encompasses the totality of customer interactions. These companies are putting the customer at the forefront of their marketing strategy instead of focusing on the product's functional features and benefits. Increasingly, companies mine customer experience when creating a new marketing strategy. These days, the customer experiences not only include interactions through traditional offline channels, but also online channels such as website, social media, and other communication mediums. According to Schmitt (1999), traditional marketing and business concepts provide little guidance for capitalizing on the emerging experiential economy: "Traditional marketing was developed in response to the industrial age, not the information, branding and communications revolution we are facing today."

Omni-channel is a cross-channel business model that companies are increasingly using to enhance the customer experience. This approach includes channels such as physical locations, FAQ webpages, social media, live web chats, mobile applications and telephone communication , and even customer's pre-purchase shopping behaviours (Wasserman, 2015; Fallon, 2014; Dholakia, Zhao and Dholakia, 2005; McGoldrick and Collins, 2007).

Consumers no longer purchase products or services solely for its features and benefits. They want something more ethereal, that they can enjoy product and services to enrich their life. That something is the customer experience. In particular, Schmitt (1999) takes issue with the features and benefits approach of traditional marketing: "In traditional model, consumers are thought to go through a considered decision-making process, where each of the features or characteristics of a particular product or service are seen to convey certain benefits, and these are all assessed by the potential purchaser either consciously or unconsciously".

The customer experience was introduced by Holbrook and Hirschman's empirical study of consumption in early 1980s and a theoretical framework for customer experience has been established in late 1990s (Holbrook and Hirschman, 1982; Pine and Gilmore, 1998). Schmitt (1999) detailed five different types of experiences, also known as Strategic Experience Modules (SEMs), which include sense, feel, think, act, and relate. He emphasized that they are becoming increasingly important to consumers' perceptions of brands.

Since companies or marketers need to not only understand what types of experiences they want to provide to their customers, but also come up with effective means to manage customers' experience, understanding antecedent factors that affect customer experience is critical (Lee, 2006). However, empirical studies that investigated the relationship between customer experience and antecedent variables in the retail environment are scarce. Recently, several studies have examined this relationship, but most focused on conceptual models, falling short of explaining the causal relationship between customer experience

and antecedent factors (Verhoef, et al., 2009; Grewal, Levy and Noci, 2009; Lee, 2011). Therefore, studying the relationship between the customer experience and the antecedent factors (i.e., experience providers) in the retail environment is vital.

Previous studies focusing on the relationship between customer experience and consumer behaviour outlined store attitude and customer satisfaction as the outcome variables of customer experience (Chiu, et al., 2012; Kuo, Hu and Yang, 2013; Srivastava and Kaul, 2016).

Thus, the purpose of this study is to establish the concept and antecedent variables of the customer experience in retail store, and then sought to verify the relationship between them. We also examined the effect of the customer experience on customer satisfaction and store attitude, which are outcome variables of customer experience. Finally, the mediating role of Omni-channel shopper type in the customer experience and store attitude relationship was investigated.

2 THEORETICAL BACKGROUND

2.1 Customer Experience

Meyer and Schwager (2007) defined customer experience as an internal response or a personal response that could be directly or indirectly linked to the company. Gentile, Spiller and Noci (2007) demonstrated that customers have a memorable experience when they are stimulated by unique experiences, all senses, emotions, relationships, and physical aspects. Therefore, they defined the customer experience as being generated not only by the customer's personal value but also by the contribution of the experience the company provides. Kotler, et al. (2009) mentioned that customer experience is adding value for customers purchasing products and services through customer engagement by managing all aspects of the encounter. Schmitt's study (1999) is the most representative in the field of customer experience research. He classified customer experience into five dimensions: sensory, emotional, thought, behavioural, and relationship experiences. Using Schmitt's five dimensions, Srivastava and Sharma (2013) studied the mediating role of customer satisfaction in the relationship between the social interaction and convenience of customer experience. Rose, et al. (2012) divided customer experience into cognitive and emotional experiences. They stated that cognitive experiences are associated with thinking and mental processes, and emotional experiences are related to the moods and feelings of human. In other words, the cognitive experience is the judgment or assessment that they make when searching and buying online products, and the emotional experience is form of various emotions obtained from the experience while searching and buying products online.

2.2 Experience Producers

A study of the antecedent variables affecting customer experience in the retail environment has been established as a systematic conceptual model by Schmitt (1999; 2003), Grewal, Levy and Noci (2009), and Verhoef, et al. (2009).

Schmitt (1999) proposed the alternative framework that is based on two elements: Strategic Experience Modules (SEM), and ExPros. The SEM refers to different types of experiences, and ExPros, which is short expression for experiential providers, are the various agencies that deliver different types of experiences. ExPros include communication, verbal identity and signage, product presence, cobranding, spatial environment, electronic media, and people. Experience marketing is the principle of creating products and services that take into account all the elements of this framework. The five different types of experiences or SEM are sense, feel, think, act, and relate.

Grewal, Levy and Noci (2009) summarized the antecedent factors that influence customer experience into five categories: promotion, price, supply chain, location, and product. Verhoef, et al. (2009) also identified six antecedent variables after reviewing previous studies on brand experience, service experience, and retail experience. The six variables that he proposed are were 1) a social environment (e.g., reference group, employee, and customers), 2) a service interface (e.g., service staff, technology, and customer customization), 3) retail store atmosphere (e.g., design, scent, and temperature), 4) an assortment (e.g., diversity, uniqueness, and quality), 5) price (loyalty program, and promotion), and 6) situational factors (e.g., store type, and location). These factors can serve as independent variables for customer experience in retail stores.

2.3 Store Attitude

There are two semantic elements in the etymology of the term ‘attitude’. Both originated from Latin ‘aptus’, one of which refers to fitness or ability as an aptitude. The other one is used in art and refers to the attitude or form of sculpture (Allport, 1935). However, in social science, the attitude is an external expression that represents one's own thoughts or feelings about an object, which is a consistent tendency of reaction (21st century political science).

Bem (1970) defined attitudes as positive or negative emotions of things, people, and issues. Fishbein and Ajen (1975) defined attitudes as evaluative beliefs of individuals on the object, and emphasized the evaluation aspect between attitude object and attitude.

If the definition of attitude from the previous studies is applied to the store, the store attitude can be said to be a positive or negative emotion of the consumer at the store.

2.4 Customer Satisfaction

Since customer satisfaction is the central tenet of marketing research, it has been widely studied in the field of service marketing. Most marketing practitioners and scholars have assumed that customer satisfaction as a result of a customer behavioural pattern positively affect business outcomes (Luo and Homburg, 2007; Horváth and Michalkova, 2012; Vykydal, Halfarová and Nenadál, 2013).

Churchill and Surprenant (1982) described satisfaction as a result of compensation for buyer's purchasing costs in relation to expected outcomes. It is argued that satisfaction is an emotion of people's pleasure or disappointment in comparison to perceived outcomes of a product (Kotler, et al., 2009). The American Marketing Association (AMA) defined customer satisfaction as 1) the degree that company's products and services meet or exceed customer expectations, and 2) good evaluation by the end consumer or decision maker after purchase.

Lee and Lin (2005) also regarded satisfaction as a function of perceived outcomes and expectations. This indicates that customer's satisfaction is increasing as the outcome exceeds the customer's expectations. Otherwise, the customer may switch easily to buy another product or service. However, very satisfied customers will be much less likely to switch to other products or services. The high satisfaction and pleasure create an emotional connection to the brand, which in turn, leads to high customer loyalty.

2.5 Omni-channel and Shopper

Before the advent of the Omni-channel, one-stop shopping was way one made a purchase through only one specific channel. Recently, however, it has become possible to enjoy shopping from various distribution channels such as mobile shopping with smart devices, online stores, offline stores, or TV-home shopping.

The diversification of distribution channels has created a crossover shopping environment. This is referred to as an Omni-channel shopping which enables shoppers to move between online and offline distribution channels. As a result, the Omni-channel shopper, who is able to freely switch between offline and online stores, has emerged as a formidable force. There are two typical types of Omni-channel shoppers: showroomer and reverse showroomer. Showroomer is a consumer who searches product information offline and purchases the product online (Kim, Lee and Yoo, 2016). It is no wonder that shoppers check quality, colour, and size of the product directly at offline stores, and buy it online after comparing the prices from different websites. Reverse showroomers, who has shopping behaviour of buying the product offline after browsing it online, are increasing as well.

According to Harvard Business Review, only about a quarter of social media users in North America and the U.K. said that they are regularly showrooming, while the rate of reverse showrooming was over 40 percent of social media users.

Also, according to the 2013 Harris poll, nearly half of Americans experienced showrooming, while close to 70 percent experienced reverse showrooming (Park, 2014).

Both the showroomer and the reverse showroomer visit offline store, but their purpose is different. Showroomer visits offline store just to see and feel the product, but reverse showroomer visits offline store for actual purchase. Thus, it can be inferred that they are more likely to pursue different empirical factors since the search and purchase channels are different.

3 METHODOLOGY

As previously mentioned, the main objective of this study is to validate the relationship between 1) customer experience and store attitude, 2) customer experience and customer satisfaction, and examining the mediating role of Omni-channel shopper type in customer experience and store attitude relationship.

In order to achieve these objectives, this study used a collection of data through a survey instrument and structural equation modelling using AMOS 20.0.

3.1 Research Model

The conceptual model for this study is depicted in Fig. 1.

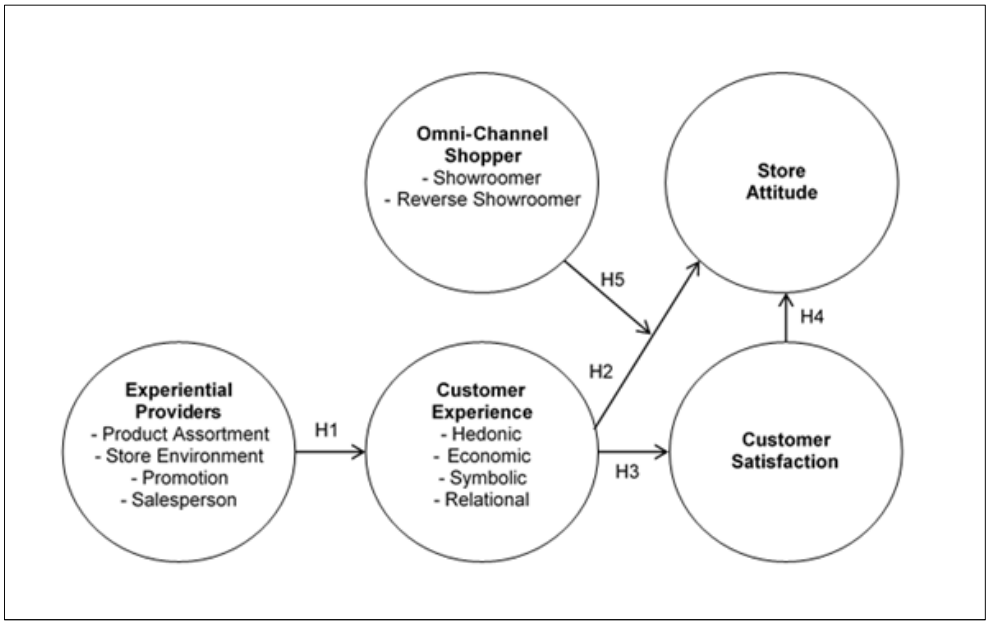

Figure 1 – Research Model

3.2 Hypotheses

Based on the above discussion, the following hypotheses were derived from the research model:

H1: The experiential provider will have a positive impact on the customer experience.

H2: Customer experience will have a positive impact on store attitude.

H3: Customer experience will have a positive impact on customer satisfaction.

H4: Customer satisfaction will have a positive effect on store attitude.

H5: The reverse showroomer type consumers will have more influence on the store attitude than the showroomer type consumers.

3.3 Data Collection

In order to test the hypotheses of this study, we conducted a quantitative survey based on the questionnaire. The survey questionnaire was conducted on customers who purchased fashion clothing at the SPA clothing brand stores in Daegu, Korea. A total of 364 items were used for the final data analysis except for the questionnaires that were not properly answered during the survey.

According to the demographic characteristics of the questionnaire used in the analysis, 174 (47.8%) of the respondents were males and another 190 (52.2%) were females. According to the ages, 15 (4.1%) were in their teens, 229 (62.9%) were in their 20s, 52 (14.3%) were in their 30s, 38 (10.4%) were in their 40s and over 50s were 30(8.2%). The average monthly income of less than 1 million won was 89 (24.5%). The marital status was 271 (74.5%) unmarried, and 93 (25.5%) married. Thus, the ratio of unmarried persons was higher. Finally, 206 students (56.6%) of university graduates showed the highest level of education.

3.4 Variables and Operational Definitions

Variables and operational definitions that were used for this study are listed in Tab. 1.

Table 1 – Operational Definitions and Measurement of Variables

Category	**Definition**	**Construct Items**	**Sources**
Experiential Providers	A strategic clue that enables marketing practitioners who want to efficiently manage and utilize their experience to effectively control their customer experience, which means product assortment, sales staff, sales promotion, and store atmosphere.	Product assortment 3 Store environment 3 Promotion 3 Salesperson 3	Thang and Tan (2003) Lee (2011)

Category	Definition	Construct Items	Sources
Customer experience	The interaction result of the hedonic, economic, symbolic, and relational experiences that customers experience when purchasing apparel products at SPA clothing brand stores.	Hedonic 3 Economic 3 Symbolic 3 Relational 3	Maghnati, et al. (2012) Nasermoadeli, et al. (2013) Shin and Oh (2015)
Store Attitude	Positive or negative evaluation of the relevant SPA clothing brand stores visited by consumers	3	Altman and Low (1992) Park, et al. (2010)
Customer Satisfaction	A comparison of customers' expectations of purchasing apparel products versus their experience with purchasing.	3	Orel and Kara (2014)
Omni-channel Shopper	Consumers who shop freely across the online and offline stores	-	-

4 DATA ANALYSIS & RESULT

In order to test the validity of the scale, factor analysis was performed using AMOS 20.0., and the reliability and validity tests were divided into internal consistency, convergence validity, and discriminant validity. The validity test for internal consistency was based on two values, the Cronbach alpha coefficient derived from SPSS 18.0., and the item-to-total correlation coefficient between the individual items of the measurement and the total mean score.

4.1 Confirmative Factor Analysis

The variables used in the confirmative factor analysis showed that the goodness of fit indices were satisfactory and acceptable. The Cronbach alpha coefficient ranged from 0.759 to 0.951, which was above the reference value of 0.6, and the item-to-total correlation coefficient also ranged from 0.714 to 0.946, which was higher than the reference value of 0.6, indicates internal consistency. The AVE (Average Variance Extracted) value ranged from 0.597 to 0.801, which is higher than the reference value of 0.5, so it can be judged that there exists convergence validity. The details are shown in Tab. 2 below.

Table 2 – Results of Confirmative Factor Analysis

Measurement scales		Internal consistency		Convergent validity			
		Cronbach Alpha	Correlation Coefficient	Loading	Error	CR	AVE
Experience Providing Tool	PA 1	.759	.806	.818	.297	.773	.597
	PA 2		.750	.758	.391		
	PA 3		.714	.741	.254		
	SE 1	.922	.860	.877	.318	.838	.742
	SE 2		.858	.864	.341		
	SE 3		.838	.843	.297		
	PR 1	.794	.812	.850	.326	.805	.692
	PR 2		.800	.841	.478		
	PR 3		.752	.805	.239		
	PS 1	.910	.861	.915	.243	.823	.801
	PS 2		.860	.898	.551		
	PS 3		.807	.871	.451		
Customer Experience	HD 1	.909	.882	.911	.307	.862	.779
	HD 2		.879	.879	.327		
	HD 3		.844	.856	.243		
	EN 1	.916	.918	.944	.441	.857	.809
	EN 2		.900	.925	.213		
	EN 3		.799	.825	.327		
	SB 1	.951	.899	.919	.481	.824	.790
	SB 2		.896	.913	.435		
	SB 3		.781	.832	.284		
	RL 1	.939	.850	.877	.349	.834	.710
	RL 2		.838	.845	.268		
	RL 3		.789	.805	.284		
Store Attitude	AT 1	.879	.905	.911	.462	.747	.769
	AT 2		.897	.872	.643		
	AT 3		.834	.847	.302		
Customer Satisfaction	SF 1	.813	.946	.958	.244	.894	.746
	SF 2		.888	.895	.169		
	SF 3		.710	.722	.179		
Goodness of Fit Indices: χ^2 (df = 362) = 629.790 (p = .00), RMR = 0.084, RMSEA = 0.085, GFI = 0.899, AGFI = 0.870, NFI = 0.937, IFI = 0.972, CFI = 0.972, PNFI = 0.779, PGFI = 0.700							

4.2 Reliability Test

Tab. 3 shows the results of the analysis of discriminant validity. Since the square value of the correlation coefficient is smaller than the AVE, the hypothesis of this study is valid.

Table 3 – Results of Discriminant Validity Test

	PA	SE	PR	PS	HD	EN	SB	RL	AT	SF
PA	.597									
SE	.537** (.288)	.742								
PR	.313** (.098)	.518** (.268)	.692							
PS	.458** (.210)	.547** (.288)	.370** (.137)	.801						
HD	.337** (.116)	.523** (.274)	.344** (.118)	.474** (.225)	.779					
EN	.332** (.110)	.380** (.144)	.382** (.146)	.327** (.107)	.304** (.092)	.809				
SB	.265** (.070)	.365** (.133)	.286** (.082)	.329** (.108)	.544** (.296)	.277** (.077)	.790			
RL	.177** (.031)	.220** (.048)	.182** (.033)	.234** (.054)	.496** (.246)	.204** (.042)	.623** (.388)	.710		
AT	.119* (.014)	.200** (.040)	.195** (.038)	.153** (.023)	.230** (.053)	.257** (.066)	.250** (.063)	.209** (.044)	.769	
SF	.417** (.174)	.519** (.269)	.345** (.119)	.413** (.170)	.569** (.324)	.471** (.222)	.419** (.176)	.430** (.185)	.383** (.147)	.746

The diagonal is the scattered extraction value, the value with ** is the correlation coefficient, and the value in () is the square of the correlation coefficient

4.3 Hypothesis Test

To verify the hypotheses of this study, SEM (Structural Equation Modelling) was performed using AMOS 20.0. As a result of the hypothesis testing, the Chi square value was 623.015 (df = 256), and RMR = 0.055, RMSEA = 0.045, GFI = 0.898, AGFI = 0.877, NFI = 0.941, CFI = 0.972, IFI = 0.955, PNFI = 0.709, and PGFI = 0.626. It can be judged that the goodness of fit indices meets the recommendation criteria and is suitable. Tab. 4 shows the results of hypotheses testing.

In order to verify the effect of Omni-channel shopper type on the relationship between customer experience and store attitude, Omni-channel shoppers were classified into two groups: showroomer (n = 109) and reverse showroomer (n = 106). As a result of the hypothesis test, H5 showed that there was a statistically significant difference between the groups at the significance level of 0.01 with $\Delta\chi^2 = 6.78$, and the standard path coefficient (0.36) of the reverse showroomer

group was higher than that of the showroomer group (0.22). Thus, the hypothesis H5 was adopted.

Table 4 – Results of Hypotheses Testing

Hypotheses	Coefficient (T-Values)	Standard coefficient	Test results
H1	0.67(6.08***)	0.51	Supported
H2	0.34(5.41***)	0.17	Supported
H3	0.15(3.22**)	0.34	Supported
H4	0.11(2.91***)	0.14	Supported
Goodness of Fit Indices: χ^2 (df = 256) = 623.015 (p =.00), RMR = 0.055, RMSEA = 0.045, GFI = 0.898, AGFI = 0.877, NFI = 0.941, IFI = 0.955, CFI = 0.972, PNFI = 0.709, PGFI = 0.626			
$^{**}p < 0.01$, $^{***}p < 0.001$			

Table 5 – Adjustment Effect according to Omni-channel Shopper Type

Omni-channel Shoppers Group Numbers	Showroomer = 102, Reverse Showroomer = 89			
Unconstrained Model	$\chi^2 = 295.095$, df = 147			
Constrained model	Group	Standard coefficient	T-Values	Test results
H5: customer experience → store attitude $\chi^2 = 301.876$ df = 154 $\Delta^2 = 6.78^{**}$	Showroomer	0.22	1.87	Supported
	Reverse Showroomer	0.36	2.65	
$^{**}p < 0.05$				

5 CONCLUSION

To survive in today's retail environment, companies need more than offer competitive price or innovative products. Perforce to say, it is not easy to garner customer enthusiasm from consumers even with lower prices and excellent product quality. Gilmore and Pine (2002) posits that the experience economy is the rightful successor to the agrarian economy, the industrial economy, and the service economy. Schmitt (1999) also predicted that the experience economy would set marketing trends: "the phenomena (the omnipresence of information technology, the supremacy of the brand, and the ubiquity of communications and entertainment) represent the early signs of an entirely new approach to marketing, if not to business as a whole. These phenomena provide the outlines of a type of marketing and management driven by experience. And within a short period of time, this new approach will replace the traditional approach to

marketing and business". As both scholars predicted, an increasing number of companies are quickly realizing that the rules of competition are changing by the day. Price and product quality remain important, but customer experience is starting to emerge as the key factor in assessing customer purchase patterns. In fact, the "new" factor may be outperforming traditional variables. It goes without saying that companies who fail to focus and deliver superior customer experience is bound for unprofitability.

The purpose of this study was to examine the mediating role of Omni-channel shopper type in relationship between the customer experience and store attitude. The second objective of this study was examining the effect of the customer experience on customer satisfaction and store attitude. To obtain those objectives, we formulated hypotheses after constructing a research model based on antecedent variables of customer experience. Based on the findings, we drew practical implications.

First, experiential providers influenced customer experience. Therefore, the retailer or marketing practitioner will need to establish effective experiential providers to offer a more satisfying experience for their customers.

Second, customer experience, (hedonic, economic, symbolic, and relational experiences), have a positive effect on store attitude. If customers are satisfied with the store attitude while they browse, compare, and purchase the products, it can lead to pleasant customer experience. In other words, customer experience proved to be an important factor in determining customer satisfaction and store attitude.

Finally, we ascertained that the reverse showroomers greatly influenced the relationship between the customer experience and the store attitude whereas it was less the case with the showroomers. Therefore, in order to inculcate the most favorable store attitude to customers, creating experience-stimulating shopping environment for the reverse showroomers can be said to be effective.

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A Study on the Quality of Life Improvement in Fixed IoT Environments: Utilizing Active Aging Biomarkers and Big Data

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ABSTRACT

Purpose: Aim of this study is to suggest a framework that can measure and assess Quality of Life (QoL) of elderly people objectively, by measuring their active aging status through biomarker sensors under a Fixed Internet of Things (IoT) and Building Information Modeling (BIM) technology environment.

Methodology/Approach: An objective QoL measurement & assessment framework that can replace previous subjective QoL measurements.

Findings: In this study, we mapped and suggested the active aging measures and corresponding biomarker sensors to derive an objective Healthcare Related Quality of Life (HRQOL) composite index so that we can replace HRQOL subjective question value. We also configured an environment to objectively measure, transfer, and store biomarker sensor values using Fixed IoT and BIM.

Research Limitation/implication: We conducted a preliminary study on establishing the relationship between the existing HRQOL survey and active-aging biomarker measurements. Moreover, the research subjects were limited to being individual elderly residents of a nursing home.

Originality/Value of paper: This study is meaningful in that it suggests a method of replacing the conventional QoL survey with objective QoL measurements through IoT sensors. Furthermore, we consider the surrounding living environment that might greatly affect the QoL of individuals.

Category: Research paper

Keywords: QoL; active aging; biomarker; fixed IoT; BIM

1 INTRODUCTION

Studies of QoL (Quality of Life) share a commonality in measuring subjects. When measuring subject's health status improvement level, most surveys ask about the number of days a subject suffered pains from specific health problems. The intrinsic weakness of this type of QoL survey question is that it can't exclude the subjectivity of responses. To overcome this weakness, we need objective measurements that utilize various sensors. In our QoL measurements, the focus of the suggested approach changes from illness to wellness. Wellness approaches suggests a new QoL scale that focuses on measuring a subject's activeness. Moreover, measuring methods that utilize sensors extend not only individual subject's health status measurements, but can also reflect improved levels in group QoL. In order to improve a specific individual's QoL level, knowledge on the interactive behaviours of the group that they belong to is also important.

The emergence of wellness approaches, managing general lifestyles to improve an individual's QoL, lead to the term 'active aging' along with the advent of aging societies. Active aging is a concept that promotes the maintenance of a physical, cognitive, and emotional health status of the elder persons, thus allows them for continuous, active participation in daily and social life into old age (WHO, 2002).

To realize goals of the active aging, we should consider the use of biomarkers for measuring general aging status. These biomarkers measure the status of a subject's organs including heart, lungs, kidneys, muscles, nerves, bones, hormones and skin. Many active aging biomarkers rely on sensor measurements.

As previously mentioned sensors for measuring QoL are an integral part of IoT (Internet of Things), a combination of IoT and QoL is realized. In the past, we have used temporary mobile sensors by physically attaching them directly to subjects when we wanted to measure their health status.

In addition to these temporary mobiles sensors, fixed sensors; which are attached to a particular structural location permanently and measure a group of subjects and their environmental status; are also needed. These fixed sensors allow us to collect environmental data in a single space and measure group health status within the space simultaneously. To utilize fixed sensors, a wireless communication standard of a fixed IoT should be primarily considered. In this study, we utilize a Zigbee communication method.

To record real-time information through the measurement of fixed sensor data, an application of BIM (Building Information Modelling) technology that integrates and manages building's structural and usage information is essential. BIM adopts IFC (Industry Foundation Classes) whose main role is an information exchange. IFC standard was developed to express a variety of real-time data in the general construction field of buildings, and to show real-time data during the life cycle of the building (Choo, 2010).

By integrating all of the suggested technologies and standards, we suggest a framework that can measure and assess QoL of elderly people objectively, by measuring their active aging status through biomarker sensors under a fixed IoT and BIM technology environment.

2 LITERATURE REVIEW

We examined the existing literature related to such keywords as QoL, active aging, biomarkers, fixed IoT and BIM. We have noted a combined study on IoT and BIM, whose authors proposed a design process using a symbiotic interaction model between a smart analog model and a digital model to realize a smart architectural space design (Kim and Kim, 2014). Another study introduced how an IoT and active-aging combination, could present a cross platform communication (Konstantinidis, et al., 2015). These authors illustrated that web based IoT platform with a disease management tool, could provide a feasible vehicles for a combined infrastructure system. Yet, efforts like ours study to integrate QoL, biomarkers, and BIM remain as a very novel approach.

2.1 Definition and Indices of QoL

Discussions of problems related to quality of life (QoL) have been recorded in USA since the 1960s, while academic efforts regarding QoL problems began in Korea in the mid-1970s, becoming truly active in the 1980s (Kwen, 2008). According to WHO, QoL was defined as an individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns (WHO, 1998). ISOQOL (International Society for Quality of Life Research) defined Health-Related Quality of Life (HRQOL) as follows: “There is broad agreement that HRQOL is the functional effect of a medical condition and/or its consequent therapy upon a patient”. And the CDC (Centers for Disease Control and Prevention) has defined HRQOL as “an individual’s or group’s perceived physical and mental health over time” (CDC, 2000).

Types of scales used in existing studies to evaluate QoL varied widely, while sharing common indices reflecting physical and mental aspects. Table 1 displays the QoL scales that have been used.

Table 1 – QoL Index in Existing Studies

Title	Author (year)	QoL index	Details
Centers for Disease Control and Prevention. Measuring healthy days: Population assessment of health-related quality of life	CDC (2000)	HRQOL	recent pain, depression, anxiety, sleeplessness, vitality, current activity limitation

Title	Author (year)	QoL index	Details
Measuring QoL with SF-36 in Older Americans with TBI	Yang, et al. (2012)	SF-36	general health, physical function, role-physical function, body pain, vitality, social function, role-emotional function, mental health
Effects of a Cognition Activation Program for the Institutionalized Old-Old in Korea	Lee and Lee (2013)	WHOQOL	physical health, psychological health, independence, social relationship, economic level, life environment level
The psychometric properties of the German version of the WHOQOL-OLD in the German population aged 60 and older	Conrad, et al. (2014)	WHOQOL-OLD	sensory activities, autonomy, past & present and future activities, participation, death and dying, intimacy
The Effects of Mental Health on the Quality of Life After Stroke	Kim and Shim (2015)	SS-QOL	energy, family role, language usage, movement, mood, individual personality, self-help activity, social role, thinking skill, sight, work-production activity
The effect of the multi intervention program applying to dementia elderly	Kim, et al. (2015)	GQOL-D	physical, psychological health, independence level, social relationship, environment, religion
Dimensions and correlates of quality of life according to frailty status: a cross-sectional study on community-dwelling older adults referred to an outpatient geriatric service in Italy	Bilotta, et al. (2010)	OPQOL	life overall, health, social relationships and participation, independence, control over life, freedom, home and neighbourhood, financial circumstances, psychological and emotional wellbeing, leisure, activities and religion
Comparison of QoL-AD and DQoL in elderly with Alzheimer's disease	Wolak-Thierry, et al. (2015)	QOL-AD	interpersonal relationships, financial difficulties, physical condition, memory, mood, overall health

2.2 Establishing Linkage between QOL Health Problem and Active Aging Bio-markers

The United States Centers for Diseases Control and Prevention (CDC) presents HRQOL as consisting of 3 modules: healthy days core module, activity limitations module, and healthy days symptoms module. Within the activity limitations module, 14 major health problems are indicated. In parallel, 18 active aging biomarkers are used for elderly people. Most of the biomarkers are applied to such body fluids as blood and urine. The linkage between 5 health problems and the active aging bio-markers are given in Tab. 2.

Table 2 – Linkage between HRQOL's Health Problem and Active Aging Bio-markers (Quantified Health, 2015)

Bio marker	Active aging bio-marker	Health problems
b1	Glycated hemoglobin level (HbA1C) (blood sugar)	h11 diabetes
b2	Cardiorespiratory Fitness (estimate of VO2 max)	h8 heart
b3	Anthropometry (body measurements e.g. BMI, waist-hip ratio)	
b4	Lung function	h5 lung
b5	Blood pressure	h10 hypertension
b6	Leukocyte telomere length	
b7	Creatinine clearance	
b8	Urea nitrogen	
b9	Lipoprotein (a)	
b10	Non-fasting Triglycerides, Total cholesterol, and High-density lipoprotein (HDL) cholesterol	h9 stroke
b11	Gum health (combined attachment loss)	
b12	White blood cell count	
b13	C-reactive protein (hsCRP) (measure of inflammation)	
b14	Apolipoprotein A1	
b15	Apolipoprotein B100	
b16	Albumin	
b17	Alkaline phosphatase	
b18	Cytomegalovirus Optical Density (presence of antibodies against CMV))	

Fig. 1 illustrates the average biomarker value changes over 12 year period (Belsky, et al., 2015).

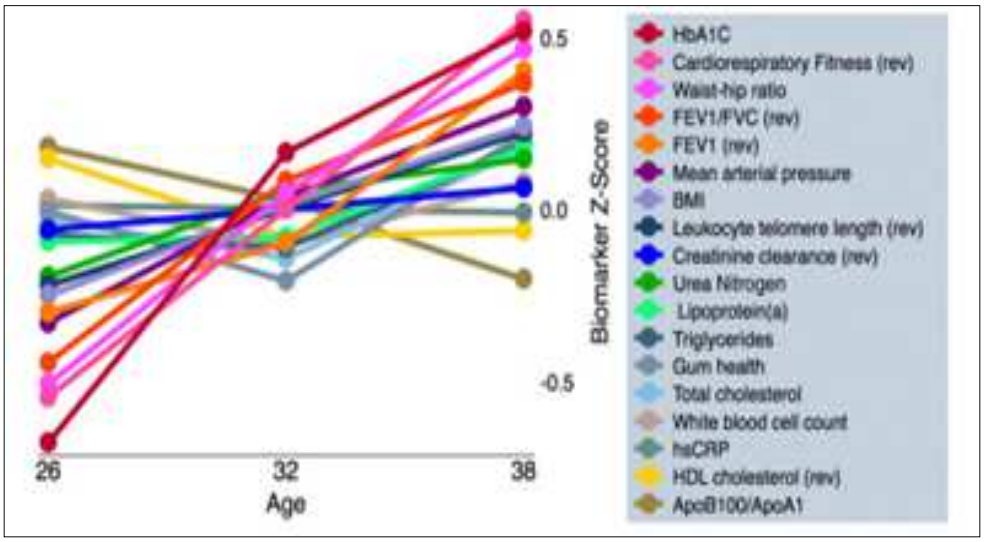

Figure 1 – Changes in Bio-markers during Aging

Other physical health problems including h1 arthritis, h2 back/neck problems, h3 fractures, and h4 walking problems can be measured by checking Bone Mineral Density (MBD), and Electro-physical tests such as EMG (Electro Myo Gram). Mental health problems are identified through electroencephalogram (EEG). Ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) scans are used for identifying both musculoskeletal health problems and structural abnormalities in the brain. Table 3 illustrates another set of biomarkers.

Table 3 – Other bio-markers and related health problems

Classification	Health problems	Bio-markers	Measurement object	Inspection method	Normal range
heart	h8	b2	ECG/EKG	current test	60~100 heartbeat per minute
lung	h5	b4	lung capacity	breath test	male: 3,500 ml female: 2,500 ml
muscle	h2	·	EMG	current test	balance of muscle in small waveform
fat	·	b3	body fat	current test	male: 10~18% female: 20~25%
bone	h3	·	bone density	radiographic inspection	T value should be over –1.0
kidney	·	b7	creatinine level	blood test	male: 0.6~1.1 mg/dL female: 0.4~0.8 mg/dL

2.3 Fixed IoT Environment

Within the nursing home, a main server connects to several master IoTs in living quarters, restaurants, gardens, gyms and playing areas via hard wired and/or wirelessly connections. In this case, the nursing home becomes a smart building providing a smart built environment (SBE), or a fixed IoT environment. The main server is equipped with a Zigbee communication module so that the server itself can be a master IoT. The server is also connected to the external communication network (Fig. 2).

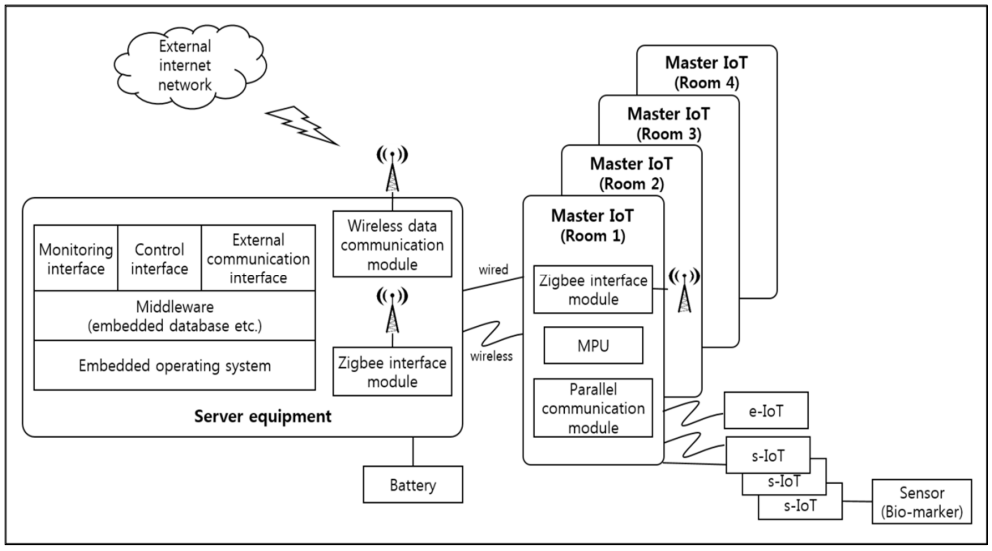

Figure 2 – Fixed IoT environment in a nursing home

A master IoT is assigned to a specific area in a form of fixed IoT. A master IoT collects data from an e-IoT and several s-IoTs through wireless Zigbee communication. An e-IoT is used to identify the subject, in this case an elder resident of the nursing home. One type of s-IoT senses the health status of the elder resident in the nursing home through biomarkers, while the other type of s-IoT senses the environmental information of the nursing home (Fig. 3). The typical data transmission rate of Zigbee (IEEE 8002.15.4) is less than 250k bps and has less than 65,500 nodes. The topology of Zigbee could be 1:1, 1:n, or mesh.

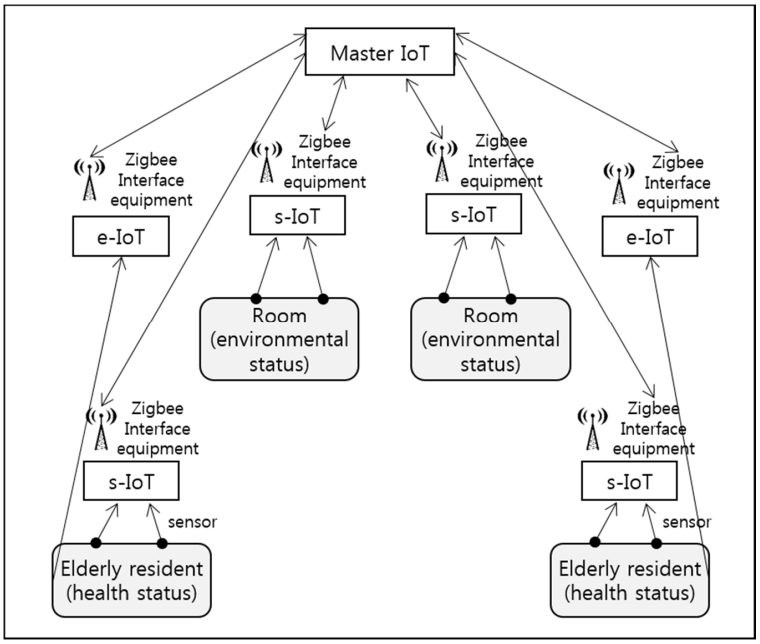

Figure 3 – IoT Communication Method in a Nursing Home

A master IoT use a 447 Mhz RF module (AirBon F400SN), a main MPU (ATxmega256A3BU 8/16 bit), and several RS232 sensor node input ports. Main power is provided by 1 cell lithium-polymer battery (3.7 V, 3150 mAh). An MPU provides low power and sends TXD while receiving RXD to and from an RF module, while sending RF/STATUS LED to the server. The data on health status of subject is grouped into a frame (Tab. 4).

Table 4 – Health Status Data Frame

Frame	e-IOT (from)	Time stamp	Sensor data (s-IOT) Z value			
			Systolic blood pressure	Diastolic blood pressure	Blood sugar level	....
^D1MA1	....	....	+value: high 0 : mean -value: low	+value: high 0 : mean -value: low	....	....

Data transmission protocols for both environmental status and group health status are based on s-IoTs equipped with bio-markers as set up as in Tab. 5.

Table 5 – Data Transmission Protocol

Attribute	NAME	TYPE			LENGTH	VALUE	DESCRIPTION
		S_ID	V_TYPE	V_ID			
Health Status	Blood pressure	0x01	0x00	0x02	0x0004	0x000 00000	Max Value: 220 (Unit: mm Hg)
						0x000 00010	Min Value: 60 (Unit: mm Hg)
Environmental Status	Temperature	0x91	0x00	0x04	0x0004	0x000 0BC0	Min Value: -60.00 (Unit: ℃)
						0x000 05A00	Max Value: 90.00 (Unit: ℃)
	Humidity	0x92	0x00	0x06	0x0004	0x000 00000	Min Value: 00.00 (Unit:%)
						0x000 06400	Max Value: 100.00 (Unit:%) (Weekly)

2.4 BIM (Building Information Modeling) and SBE (Smart Building Environment)

In a smart nursing home building, the residents are referred to the 'building occupants', whose personal safety, comfort and health status are of concern. To reflect such information, a variety of smart objects will be ubiquitously and transparently installed in the Smart Built Environment (SBE) to perform actions, such as sensing and control (Zhang, Seet and Lie, 2015). Especially sensors are installed according to the range space or the effective sensing space area. The range space of a sensor is represented by a range radius and range angle. Storing such information refers to Industry Foundation Classes (IFC) Building Information Modeling (Fig. 4).

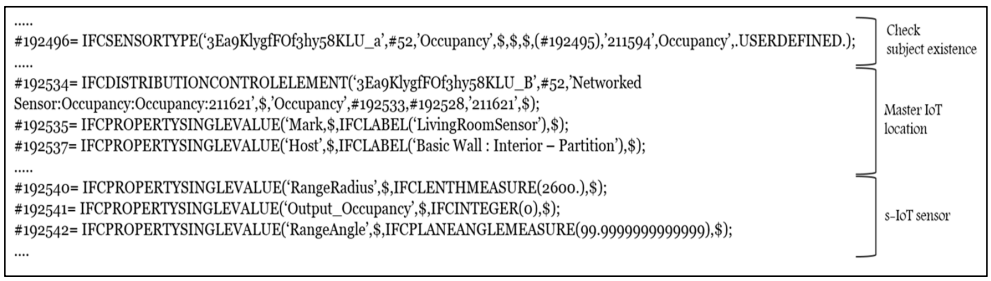

Figure 4 – Code Segment of the Building Information Modelling IFC File for s-IOT

SBE serves to enhance the building's efficiency, security, and comfort of its human occupants by being aware of the state of the environment and performing

autonomous intelligent actions. Such actions performed by the SBE can be viewed as provisioning a type of service to occupants. These intelligent actions will be dealt with in future studies in a form of either immediate feedback or long term recommendation plans.

The IFC (Industry Foundation Classes) data model is the international standard open file format for BIM. It compiles a variety of information in an overall construction within a schematic structure. IFC schema includes the information structure between space structure foundations that form spaces. Also, the key data of IFC schema mainly consist of IFC Kernel, IFC Control Extension, IFC Process Extension, and IFC Product Extension. Tab. 6 displays the typical specific elements that are included in the IFC schema.

Table 6 – Detail Elements of IFC Schema

IFC schema	**Detail element**	**Examples**
IFC Kernel	Controls, Instruments	sensor, actuator, controller, gauge, meter
IFC Product Extension	Environmental Impact	embodied energy, CO_2
IFC Kernel	Actors	people, addresses, organizations

For environmental factor values for indoor environments; which are needed for the environment setting of fixed IoT; factors suggested in the environmental impact indicators of 'IFC4' can be utilized. Among the 16 factors therein, factors such as Climate Change per Unit or Atmospheric Acidification per Unit can be set as the environmental factor values (Tab. 7).

Table 7 – Factors of Indoor Environmental Elements

Environmental element	Measuring value
Climate Change Per Unit	Quantity of greenhouse gases emitted calculated in equivalent CO_2
Atmospheric Acidification Per Unit	Quantity of gases responsible for the atmospheric acidification calculated in equivalent SO_2

3 RESEARCH PLAN

3.1 Framework

In this study, we suggest an objective QoL measurement & assessment framework that can replace previous subjective QoL measurements. The proposed framework is subdivided into 5 parts: HRQOL, Active-aging & Bio-markers, Fixed IoT & BIM/IFC, Derive active-aging & HRQOL index, and

Establish linkage HRQOL questionnaire & active-aging index. Fig. 5 illustrates the proposed framework.

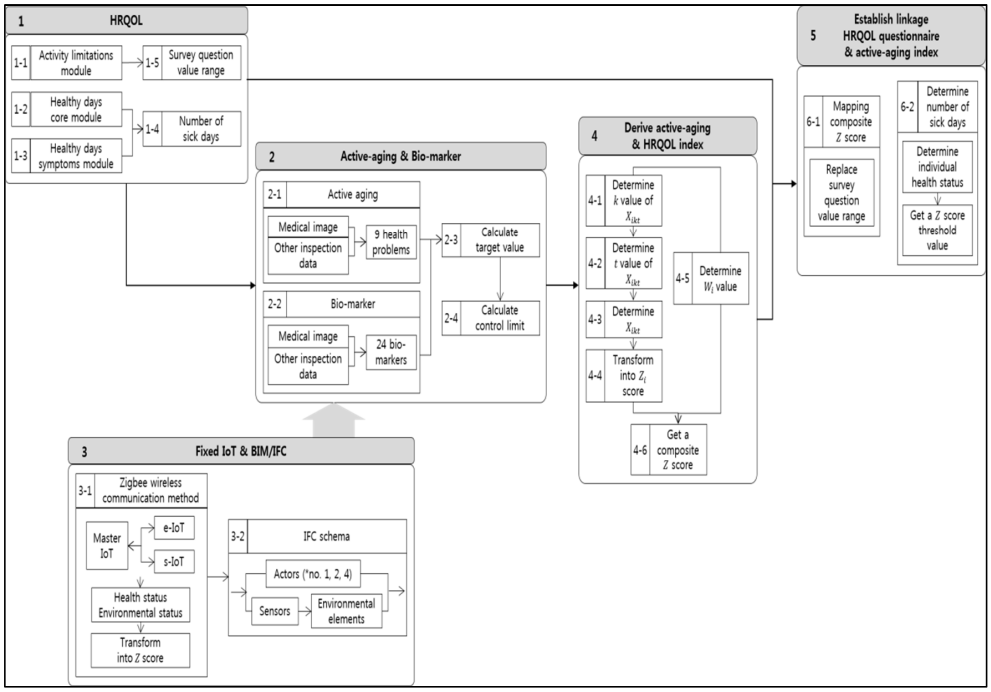

Figure 5 – Proposed Research Framework

3.2 HR QOL

The CDC HRQOL is composed of 3 modules: healthy days core module, activity limitations module and healthy days symptoms module. There are two types of questions: one asking whether or not the respondent is under a certain health condition, and the other asking the number of sick days experienced over the past 30 days. For example, the activity limitations module includes a question on whether the respondent's activities are limited or not. Whereas, the healthy days core module covers the question on the number of sick days in the month; the activity limitations module has a question on the duration of activity limited; and healthy days symptoms module covers questions relating to the number of days of having pain, and having not enough rest and sleep.

3.3 Active-aging & Bio-marker

14 major health problems are mentioned in the activity limitations module of HRQOL. Among these, we focus on diabetes, heart problems, lung problems, hypertension, and stroke. In addition, we consider arthritis, back/neck problems, fractures, and walking problems. In active ageing, 18 biomarkers are under consideration. We will also consider ECG/EKG, lung capacity, EMG, body fat,

bone density, and creatinine levels. Collectively we consider in this study, 9 health problems and 24 biomarkers.

For the 24 biomarker sensor values, we obtained target values and control limits from Clinical Practice Guidelines (CPG).

3.4 Fixed IoT & BIM/IFC

In the Fixed IoT environment, we employ Zigbee wireless communication methods equipped with several master IoTs having e-IoT for subject identification and s-IoT for sensors measuring health status of subjects and environmental factors.

In addition, the information transmitted from 'Sensors'; a sub-item of IFC Kernel; is stored in the form of IFC schema. IFC Kernel stores the information on environmental elements too. Also 'Actors', another sub-item of IFC Kernel, serves to record the information on biomarker values.

3.5 Derive Active-aging & HRQOL Index

Active aging index is a composite weighted Z score of all bio-markers' Z score values. To determine the health status of elder people, we consider 24 bio-markers, mostly based on body fluids and medical images (refer to the literature review section). Observed values of bio-marker X_i take a form of a data stream, having k consecutive values over a time period from *0* to *t*. We use CUSUM (cumulative sum) of X_{ikt} over k to determine the time ´t´ when CUSUM value reaches a threshold level. After t and k are determined, we transform each biomarker value X_{ikt} into a Z_i score. As 99% of Z score values are in range between -3 and 3, Z^2, the square value of Z score ranges between 0 and 9. The weight of each Z score is between 1 and 99 where the sum of all the weights is 100. The relative weight of each bio-marker is determined by its representativeness for health status of an elderly person. Although elder people suffer from multiple health problems, the major health problems were chosen for each bio-marker's representativeness (for example, blood pressures represent hypertension). By taking the 200^{th} root of a composite multiplication of all the Z_i to the W_i, we are able to get a composite Z score ranging 0 to 3.

3.6 Establish Linkage HRQOL Questionnaire & Active-aging Index

Mapping the composite score (whose value ranges between 0 and 3) to the value of a HRQOL survey question (whose value ranges between 1 and 4), is simple. However, determining the number of sick days (among the most recent 30 days period that result from a certain health problem), using day by day composite scores is not an easy matter. To overcome this, we would conduct a backward research to get matching HRQOL survey data of elder residents of a nursing home, along with their 30 day composite scores that are obtained from several biomarkers' values for determining active aging health status. By counting the

composite scores of each resident in descending order, relative to the number of sick days, we could get the composite score threshold value for determining the individual resident's health status in terms of sick days. By collectively distributing obtained threshold values of all the residents, we could get a mean and standard deviation of composite score threshold values for determining the number of sick days resulting from a major health problem. Lastly, we suggest using an algorithm to replace HRQOL survey values into an active-aging index, applying configured materials as before.

4 PRELIMINARY EMPIRICAL ANALYSIS

4.1 Converting Bio-marker Values in a Form of Data Stream into a Single IoT Sensor Value at a Certain Time Point

Bio-marker values are converted into Z-scores (numbers of standard deviations above or below the mean). The Z score of a bio-marker i, whose observed value X_{ikt} where k denotes the k_{th} observation in the data stream at the time t, is represented as following:

$$Z_i = (X_{ikt} - M_i)/\, S_i \tag{1}$$

where M_i is a mean value and S_i is a standard deviation of bio-marker i. To get the single observed value from the data stream, we plan to apply either Mei's algorithm (Mei, 2010) or Tartakovsky's algorithm (Tartakovsky, 2006) to determine the observation point in time T.

According to Mei (2010), $T(a)$ is defined as following:

$$T(a) = inf\left\{t: min_k \sum_{k=1..k} CUSUM(X_{ikt}) \geq \ threshold\ value\ a\right\} \tag{2}$$

According to Tartakovsky et al. (2006), $T(b)$ is defined as following:

$$T(b) = inf\{t: min_k CUSUM(X_{ikt}) \ \geq \ threshold\ value\ b\} \tag{3}$$

Some bio-markers are constantly checking the body status and transmitting the value in seconds whereas the others are generating values in hours. Most of the bio-markers are creating a single data stream while others are generating multiple data streams. For example, blood pressure has the top number (systolic) and the bottom number (diastolic). Mean values of 120 over 80 (120/80 mm Hg) are used. We have observed 26 hypertension patients out of 508 subjects during the

years 2013 and 2015. Their systolic blood pressure ranged between 110 and 220 whereas diastolic blood pressure ranged between 60 and 126.

4.2 Deriving HRQOL Composite Index Augmented by Real Time IoT Sensor Values

The Z_i value of the HRQOL index that is based on a single bio-marker is defined by using utility transformation function. Z_i is defined as the desirable degree of each test result value. There are 4 types of normality judgement for these check values: 'within specific range', 'larger than specific value', 'smaller than specific value', and 'in specific qualitative value' (Fig. 6).

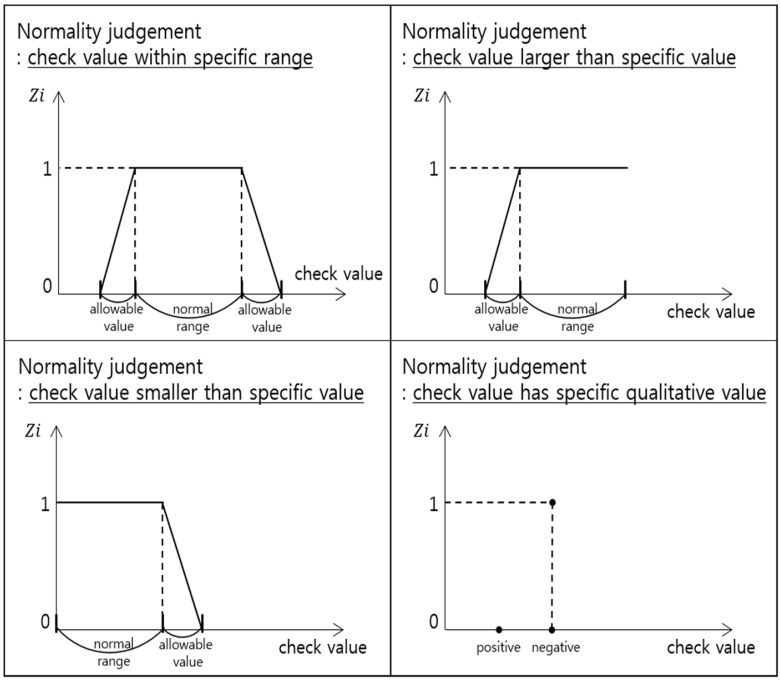

Figure 6 – Control Limits of Check Value in Normality Judgement

Also, the formula that calculates the overall HRQOL composite index that decides synthetically the following location of test result values is proposed below.

HRQOL index based on single bio-marker *Zi*.

Overall HRQOL index $= \sqrt[200]{Z_1^{2w1}} \cdot Z_2^{2w2} \ldots Z_k^{2wk}, W = w_1 + w_2 + \cdots w_{1k} = 100$

4.3 Establishing Linkage between HRQOL Questionnaire and HRQOL Composite Index

Within the CDC HRQOL 'healthy days core module', a subjective question asking the number of days when physical health was not good (over the previous 30 days) could be replaced with an objective HRQOL composite index.

Within the CDC HRQOL 'activity limitations module', a subjective question on the duration of limited activities due to a specific health problem could be also determined by the objective HRQOL index.

Within the CDC HRQOL 'healthy days symptoms module', a subjective question on the number of days having pain, and another question on number of days having not enough rest and sleep, could likewise be measured by the objective HRQOL index.

For an illustrative purpose, we have observed 30 composite indices of each day's systolic blood pressure level during the recent 30 days (Tab. 8) and obtained HRQOL survey answers indicating the number of days that a typical elderly person suffered from his/her hypertension, (for example, 5 days of limited activities, 10 sick days due to hypertension, 12 days having pain, and 15 days having not enough rest and sleep). From the descending order of data stream of composite indices (Tab. 8), we located the 5th, 10th, 12th, and 15th composite index values of systolic blood pressure level. Using these values as threshold values for determining the number of days suffered for hypertension from other elder people's data streams of composite indices. For example, we add one more day for the number of days 'not having enough rest and sleep' if the subject's composite index of systolic blood pressure level is higher than 0.997890. Likewise, we add one more day for the number of days of 'limited activities' if the subject's composite index of systolic blood pressure level is higher than 2.757575. Of course, if the systolic blood pressure level is so high, we also add one more day for the number of 'sick days', for the number of 'days having pain', and the number of 'days not having enough rest and sleep'.

Table 8 – The Descending Order of Data Stream of Composite Indices of Each Day's Systolic Blood Pressure Level during Recent 30 Days

Day	Composite index value	Day	Composite index value
1	3.030303	16	0.997891
2	3.030303	17	0.997891
3	2.757576	18	0.939394
4	2.757576	19	0.909091
5	**2.757576 (5th composite index value)**	20	0.909091
6	2.090909	21	0.909091

Day	Composite index value	Day	Composite index value
7	2.090909	22	0.606061
8	1.939394	23	0.606061
9	1.666667	24	0.606061
10	**1.363636 (10th composite index value)**	25	0.606061
11	1.212121	26	0.303031
12	**1.181818 (12th composite index value)**	27	0.110342
13	1.181818	28	0.110342
14	1.030303	29	0.110342
15	**0.997891 (15th composite index value)**	30	0.110342

Within the CDC HRQOL 'activity limitations module', a question on whether activities are limited or not, and questions on "whether or not another person's help is needed for personal care/ needs and routine needs, due to a specific health problems" could be determined from the objective HRQOL index by directly mapping an index value of 0 to the question value of 1, and mapping an index value of 3 to the question value of 4.

5 CONCLUSION

In this study, we mapped and suggested the active aging measurements and corresponding biomarker sensors that can replace the CDC HRQOL subjective questions value, and configured an environment to objectively measure the previously suggested list using Fixed IoT and BIM/IFC. In this regard, we suggested a framework for obtaining HRQOL questions values from active aging composite indices.

This study is meaningful in that it suggests a method of replacing the conventional QoL survey with objective QoL measurements through IoT sensors. For elder people, in some cases, they cannot reply to the questionnaires accurately/ objectively because of physical conditions. Even in such cases as these, the method suggested in this study enables us to measure and evaluate the QoL of these elder people.

Furthermore, we consider the surrounding environment that might greatly affect the QoL of individuals. Therefore, in this study, we measured the environmental status as well as health status, considering a range of elements to improve the QoL of the subjects in general.

Additionally, in this study, we configured the network topology to exchange sensor information in an indoor environment using fixed IoT and IFC technology which has not been suggested in any previous studies.

However, in this study, we mainly focused on establishing a relationship between the existing HRQOL survey and active-aging biomarker measurements. Our study focused on deriving a feasible method for augmenting extant subjective HRQOL index by the use of objective, real-time IoT sensor values. Moreover, the research subjects were limited to being individual elderly residents of a nursing home.

We plan to expand the scope of the research to include group level HRQOL in addition to individual level HRQOL. Much of the emotional HRQOL and activity limitations are known to be affected by interactions among neighboring group members. We expect the group HRQOL dynamics will result in upward or downward shifts of individual composite indices.

At this research stage, monitoring trends of composite indices draw our attention. Based on this preliminary result, we plan to devise a feedback mechanism to enable an upward shift of composite indices. In the end, we expect to come up with both individual and small group recommendation practice guidelines for improving HRQOL.

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Application of IoT for the Maintaining Rolling Stocks

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ABSTRACT

Purpose: This paper presents a framework for simulation on IoT based CBM (condition based monitoring) for rolling stocks. This enables to allocate maintenance resources effectively while satisfying preventive maintenance requirements.

Methodology/Approach: We exploits Reliability centered maintenance (RCM) based on KTX (Korea Tran eXpress, Korea's high-speed rail system) motor reduction unit failure data for three years by utilising the internet of things (IoT) and RAMS (Reliability, Availability, Maintainability, Safety) methods.

Findings: We come up with the predictive maintenance indicator; reliability functions as to the desired service level; and the failure and defect prediction indicator takes the form of cumulative failure function in the form of probability distribution function, which aim to realise the real-time condition monitoring and maintaining technical support services. Internet of Things (IoT) has been an important apparatus to improve the maintenance efficiency.

Research Limitation/implication: This paper has limitations that the data are collected from references, not actual data; the detailed descriptions of IoT application to the railway rolling stocks are omitted, and it is not dealt in depth how maintenance efforts and performance are improved through the suggested reliability centered maintenance.

Originality/Value of paper: This study has the academic importance in a sense that it integrates RAMS based maintenance methods and IoT. RAMS centered maintenance provides powerful rules for deciding a failure management policy; when it is technically appropriate; and for providing precise criteria for deciding how often routine tasks should be carried out. It will lead to the improved cost efficiency, sustainability and maintainability of railway maintenance system since the staff do not have to visit installation sites frequently. Lately, there is general agreement that prevention was better than inspection and that an increase

in preventive cost was the means of reducing total quality costs. In connection with this issue, we will address the way of reducing failure costs and prevention costs with IoT: new appraisal method.

Category: Conceptual paper

Keywords: railway rolling stocks; maintenance; IoT; RAMS; PAF model

1 INTRODUCTION

The objective of a railway is to perform a defined railway traffic service safely within a scheduled time and limit budgets. The complexity of railway industry brings the necessity for seeking effective methods for day to day operation and appraising the results in the light of the long-run objectives of the railroad (Charnes and Miller, 1956). Railway RAMS management is an engineering discipline to conduct integrated systems with the policy, objectives, principles, criteria, techniques, method and tools (Park, 2016).

However, there has been a trade-off on the baseline of the RAMS both on day to day operations and long-term maintenance. For example, on day to day operation, availability trade off for safety and cost. If the goal of railway service is improving availability, which is defined in both readiness at the departure station and the arrival time at the terminal station, it will decrease safety as defined in risk assessment.

On long term maintenance, there is trade-off between reliability and availability. When railway organisations set service level to improve reliability, the ability that a system can perform its intended function over a given time without any failure, it will decrease availability performance. Moreover, failure prediction of railway system is more difficult because of complexity of the system and its insufficient data source (Park, 2016).

If we can bring IoT technology into railway industry, it will bring high impact to many aspects of the railway RAMS management. In contrast to trade off of availability, safety and cost aspect, we could see the effect of monotonic, continuous increase of availability and safety. Also, their high availability requires a significant amount of costs, but IoT cut down the cost of infrastructure technologies by distributing to common carriers. Not only that, railway operators are allowed to use efficient monitoring system and dependability RAMS management by adapting their requirements depending on railway service level and operational strategies.

It may be useful to start out by examining the effectiveness of application IoT on the railway. This paper will provide a framework for simulation on IoT based CBM (condition based monitoring) for rolling stocks. The first part discusses the background of railway management technique based on the current system state. The second part presents the research methodology which adopted IoT for long-term maintenance. We discuss the outline of methodology for the RAMS

management in IoT monitoring system with failure data. The third part provides the result of methodology. This part includes identifying the benefit of IoT implementation.

2 LITERATURE REVIEW

2.1 RAMS

RAMS (reliability, availability, maintainability and safety, IEC 62778) analysis is an important step in the design and the operation of productions and services (Barabadi, Gudmestad and Barabady, 2015). The aim of railway RAMS is achieving a defined level of rail traffic in a given time with a given safety level.

Reliability characteristic represents the ability that a system can perform its intended function over a given time without any defined failure. Maintainability is a system characteristic that designs the ease of maintenance within the structure of a system. Availability characteristic means the ability to operate a system at the starting point of the required mission whenever required by operator. Finally, safety is a system design characteristic to provide freedom from unacceptable risks with regard to operation, maintenance, person, environment, and equipment.

The RAMS definition can be tailored from the framework of Fig. 1, depending on railway service objectives and operational strategies. For example, the goal of the railway service is to achieve the level of a defined railway traffic service within the defined time and limited cost safely (Park, 2016).

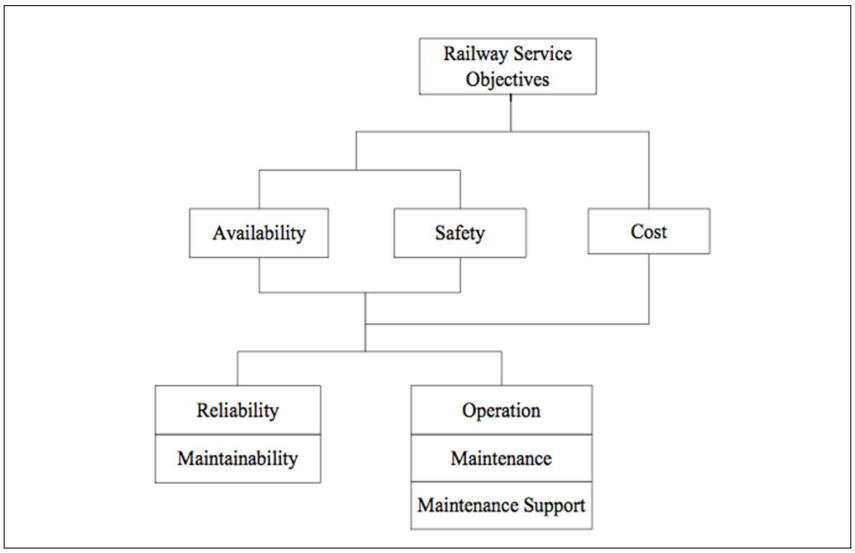

Figure 1 – Definition of Railway RAMS Elements (Park, 2016)

To improve the quality and the efficiency of railway services, acquiring the system with high RAMS performance and monitoring the operation and maintenance policies are needed (Kim, et al., 2008). Therefore, Korail specifies RAMS requirements in the system specification when it purchases the equipment and rail stocks. Also, RAMS centered maintenance procedure is needed to achieve the inherence RAMS performance of the acquired system continuously.

The importance of reliability centered maintenance (RCM) and its effect in RAMS analysis is highlighted in many literature. For example, Kim, et al. (2008) proposed the conceptual model for determining optimal maintenance interval after evaluating the effect on RAMS centered maintenance system for railway. Hameed, Vatn, and Heggset (2011) emphasized that failure mechanisms, failure models and operational conditions of wind turbines component should be collected in RAMS data based, after reviewing challenges in reliability and maintainability data collection for offshore wind turbines. Duarte, Cunha, and Craveiro (2013) showed that the reliability characteristics of equipment which is evaluated in design phase could partially change during the operational phase with huge effect on performance of production facilities. Hence, they mentioned that all the influence operational conditions should be collected in the maintenance database.

Reliability centered maintenance (RCM) is a process used to decide what must be done to ensure that any physical asset, system or process continues to do whatever its users want it to do. Therefore, RCM provides powerful rules for deciding whether a failure management policy is technically appropriate, providing precise criteria for deciding how often routine tasks should be carried out. RCM identifies ways which the system can fail during their lifespan. This must generally be followed by a failure mode and effects analysis (FMEA) which allows an assessment of the consequences of failure.

FMEA is a systematic analysis of the potential failure modes of a component of a system (Price, et al., 1995). It includes the identification of possible failure modes, determination of the potential cases and consequences and an analysis of the associated risk. It also includes a record of corrective actions or controls implemented resulting in a detailed control plan (Taylor, 1998). The FMEA allows identifying the most critical components and the likely failure mechanisms, thus leading to the specification of system parameters to be monitored.

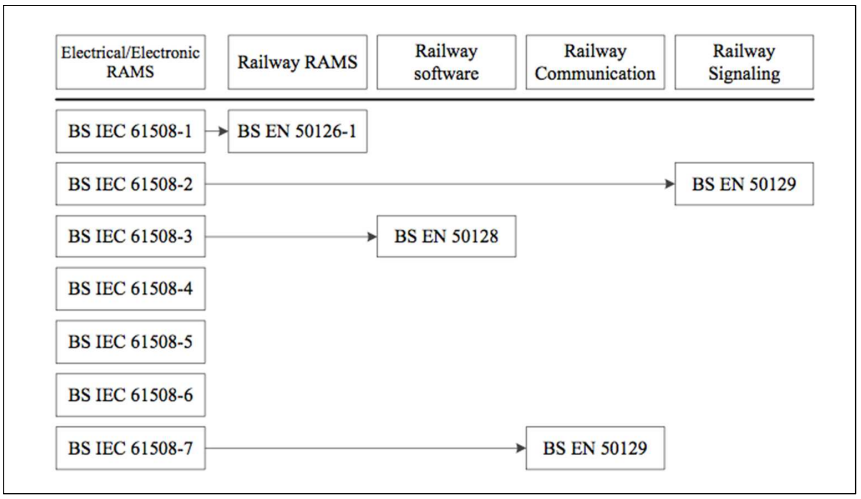

Figure 2 – Railway RAMS Management Standards (Park, 2016)

2.2 IoT Monitoring System

In practice, time based monitoring is obtained at discrete monitoring time intervals. This type of time based monitoring is called indirect monitoring in contrast to direct monitoring which measures the actual condition. The latter, condition based monitoring, employs advanced electronics, sensors, and transducers, computing and communication technology.

Internet of Things (IoT) aims to establish interconnection of objects in the physical world and integrates countless electronic devices around us and a large number of technologies into the network. Hence, cooperation with other people to achieve common goals, interaction with each other and provision of information on a real time basis through standard communication protocols and unique addressing schemes can be achieved by IoT. If we can bring IoT technology into the railway condition monitoring system, it will bring high impacts to many aspects of maintenance and greatly increase the maintenance efficiency.

To improve the maintenance efficiency and save the maintenance cost, IoT technology has been introduced into remote handling maintenance process. IoT-based remote handling maintenance process has been designed for remote condition monitoring. Especially it has been applied in a harsh environment such as an arctic region (Barabadi, Gudmestad and Barabady, 2015), and a desert area.

The system dynamically monitors, collects, records and analyzes equipment parameters to perform fault diagnosis and fault prediction; it also carries out the analysis of the changing trends of fault parameters to ascertain the degradation extent and fault location. Thus appropriate maintenance mode, trouble location, and remaining lifespan can be determined based on the system (Scarf, 1997).

2.3 Condition Based Monitoring (CBM)

Condition based maintenance (CBM) aims at achieving reliable and cost-effective operation of engineering systems such as aircraft systems, wind turbine generators, hydro power plants and manufacturing systems (Jardine, Lin and Banjevic, 2006). In CBM, condition monitoring data, such as vibration data, oil analysis data, and acoustic data, are collected and processed to determine the equipment health condition (Tian, 2007). Future health condition and the remaining useful life (RUL) of the equipment is predicted.

Thus, optimal maintenance actions are scheduled based on the predicted future equipment health condition, so preventive replacements can be performed to prevent unexpected failures and minimize total maintenance costs (Jardine, Lin and Banjevic, 2006; Levitin, 2005; Liao, Elsayed and Chan, 2006; Inman, Farrar and Lopes, 2005). Accurate health condition prediction is critical for the effective implementation of condition based maintenance.

3 METHODOLOGY

This section introduces the research methodology which adopted IoT for long-term maintenance. We present the outline of methodology for the RAMS management in IoT monitoring system with failure data.

3.1 Failure Rate Analysis of Railway Rolling Stocks

We start from the available failure history data, FMECA: Failure Modes Effects and Criticality Analysis for improving MRUs' (Motor Reduction Units) failure. KTX (Korea Tran eXpress, Korea's high speed rail system) motor reduction unit failure data for three years include driving distant values, the number of inspected railway rolling stocks and the actual number of failed railway rolling stocks.

The MRU's FMECA data does not contain part age values and part failure distributions. Age values and failure distribution of parts can be calculated in correspondence to the actual driving distance.

The failure rates of each railway rolling stock and its parts are estimated using age values and the railway stock maintenance manual.

We chose Motor Reduction Units because MRUs are one of the most important parts related to the safety of railway rolling stocks. MRUs (Motor Reduction Units) consist of a brake cylinder, a brake shoe, and a brake disc.

3.2 Reliability Function

In general, railway service RAMS measures are defined by service safety and availability as measures of service effectiveness and service reliability as

technical RAMS performance measure. The top-down methods are applied to identify and analyse the consequence scenarios of RAMS (Park, 2016).

RAMS, key performance indicators of railway rolling stock include mean time between failures (MTBF), mean time to repair (MTTR), maintenance cost, failure frequency, availability, maintainability, etc. MTBF is related to failure frequency, reliability, and availability. MTTR indicates equipment maintainability, availability, and interruption production time.

The residual lifetime of the part can be an indicator of maintenance decision making. If the usage time and the mean lifetime of parts can be measured, the residual lifetime of the part can be calculated. If the reliability function is defined as a service level, the number of parts, whose residual lifetime is greater than zero, should be greater than or equal to the service level multiplied by the total number of parts, at a given point in time.

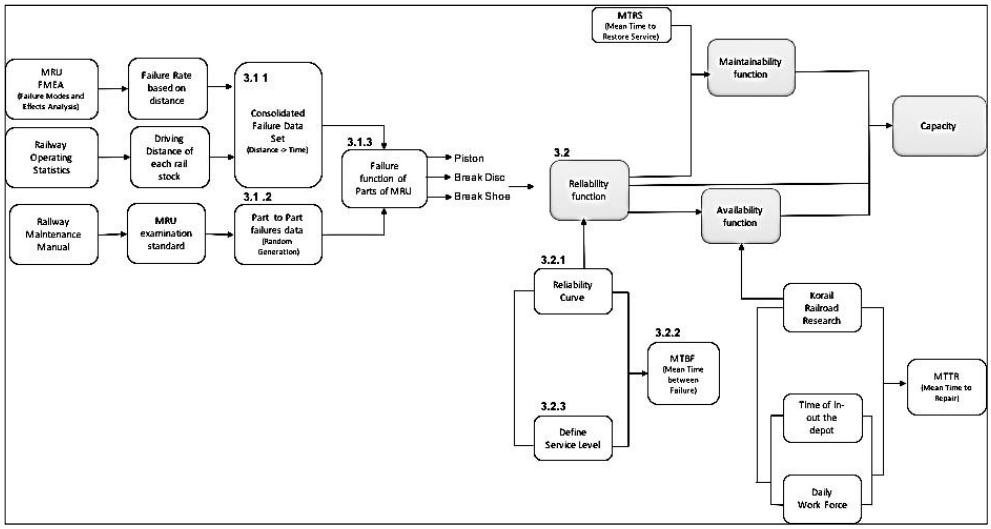

Figure 3 – Research Framework

3.3 Condition Based Monitoring with IoT

We characterize how RAMS methodology and failure data are tuned in section 3.1 and 3.2. We used RAMS as capacity analysis method, which is to determine the maximum number of trains that would be able to operate on a given railway infrastructure, during a specific time interval, given the operational conditions.

On this section, we will present how IoT data can be analysed for assessing railway capacity. Simulation methods and Optimization methods are one of the approaches to evaluate railway capacity (Abril, et al., 2008). We give a short description of simulation method with IoT and RAMS analysis.

Fig. 4 provides a model which determines the measures of RAMS effectiveness through the railway service level and establishes the performance of sensor

monitoring effectiveness through the assessment of condition based monitoring maintenance. The process consists of six activities: (1) identify all possible failure modes on parts of rolling stocks. (2) the determination of the residual lifetime of parts with reliability function. (3) the determination of operational RAMS effectiveness targets (4) the assessment of maintainability performance (5) Optimization of railway capacity (6) RAMS performance verification. The sensor's data is analyzed whether it was better methodology to improve service level so that they can predict failures and reduce maintenance time.

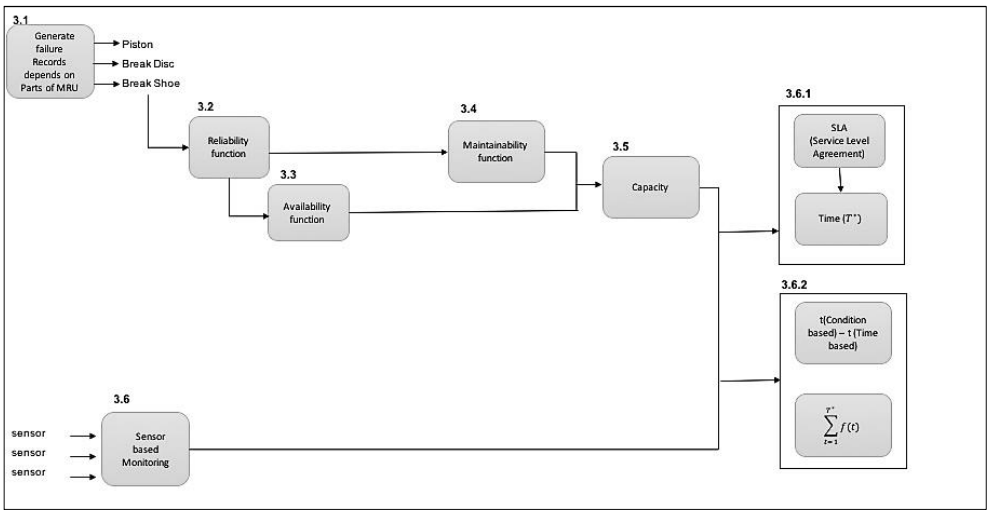

Figure 4 – Proposed CBM Monitoring Process

4 FINDINGS

This section provides how IoT implement on railway maintenance. It consists of two parts. First, we discuss failure rate analysis on railway maintenance. Next, we present failure prediction model that is applicable to cover reliability based maintenance and real time condition monitoring assessment.

4.1 Failure Rate Analysis

FMEA is useful risk assessment technique and it has been used for failure analysis of the system which can cause the failure consequences that affect railway system (Park, 2016). It is used for qualitative failure analysis of system elements, and we adapted and applied it to condition based monitoring.

As shown in Tab. 1, failure rate is increased after 1,400,000 km driving distance and radically increased after 1,800,000 km driving. The failure rate is a key indicator for obtaining the reliability and deciding maintenance points of railway rolling stocks.

To compare the effectiveness of the time based maintenance with that of the condition based maintenance, we need to convert the driving distance based inspection data as to the usage time (ages of rolling stocks). In future, when we can obtain actual rolling stock MRUs condition data from IoT sensors, this conversion process will be no longer necessary. We also need to predict each MRU part's lifespan.

Table 1 – Failure Rate Analysis on Railway Rolling Stocks

Ages (year)	Driving Distance (km)	Number of investigation	Actual number of failure	Failure Rates
4	0~600,000	3	0	0%
8	600,000~1,200,000	6	0	0%
12	1,200,000~1,400,000	6	0	0%
16	1,400,000~1,600,000	10	1	10%
20	1,600,000~1,800,000	25	3	12%
24	1,800,000~2,000,000	50	12	24%
28	2,000,000~2,200,000	65	18	28%
32	Over 2,200,000	20	9	45%

Fig. 5 offers the cumulative failure rate based on Tab. 1. The cumulative function helps to determine patterns of failure rate and to assess the extent to which each component contributes to overall failure. According to the failure prediction model, the first part failure occurs around 13 usage years.

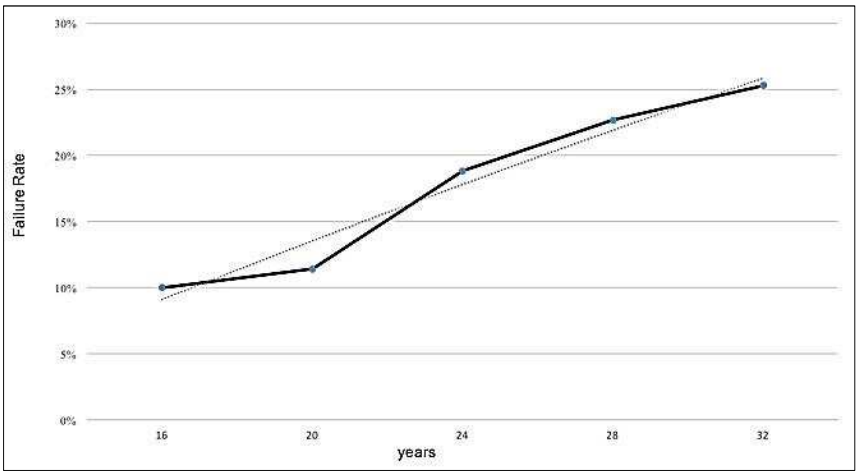

Figure 2 – The Cumulative Failure Rate

4.2 Failure Prediction Model for MRU

The prediction model carries out how much we can save lifespan of MRU.

The failure rate model could be varied. As Fig. 6 shows, failure rate could be changed by maintenance strategy.

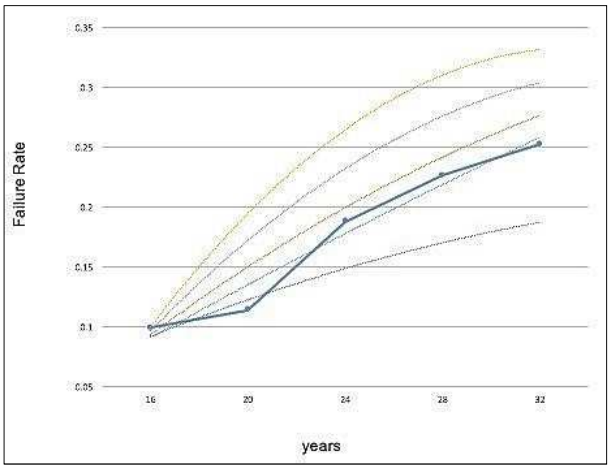

Figure 3 – Failure Rate Depending on Maintenance Performance

Another option for variation of failure rate is service level. This is possible because it defined RAMS performance level. Based on service level, RAMS performance specification is defined and it affects failure rate. The failure rate, *F(t),* is a probability complementary to reliability, as shown below:

$$F(t) = 1 - R(t) \tag{1}$$

Fig. 7 shows that if the service level is increased, reliability curve moves toward left.

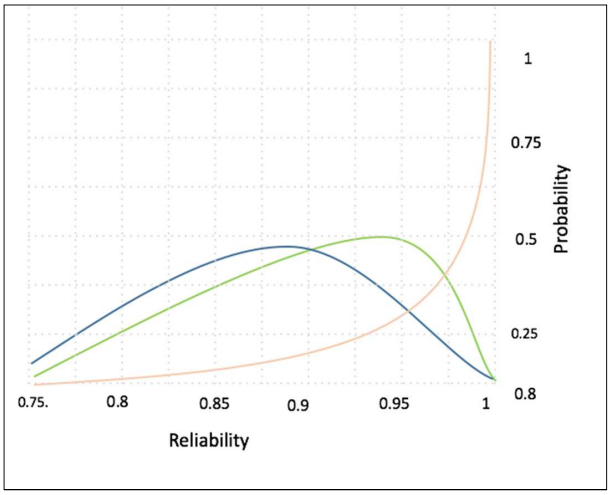

Figure 4 – Failure Probability and Reliability Probability Depends on Service Level

Following two variations for failure prediction, we define service level in most conservative case, which is operation resource is perfectly ready. It will lead to implementing of real data set more easily.

The currently available brake cylinder failure data is not sufficiently distinctive to calculate the failure rate, but we can assume the maintenance time and part investigation period for the time being until actual IoT based sensor data are obtained.

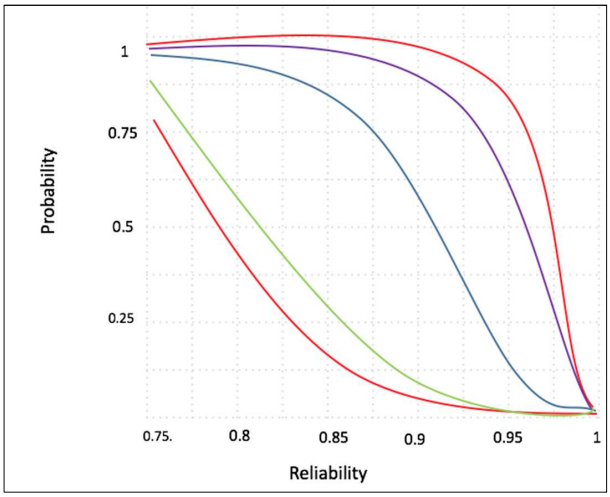

Figure 8 – Probability of Reliability Indicator for MRU Unit

5 CONCLUSION

Internet of Things (IoT) has been an important apparatus to improve the maintenance efficiency, but its application areas are limited to aircraft and building instruction fields. Also, its application has been concentrated on remote monitoring system only. Therefore, IoT based maintenance for rolling stock is expected to optimize maintenance content and maintenance periods while minimizing maintenance costs and prolonging the lifespan of equipment.

Furthermore, this study has the academic importance in a sense that it integrates RAMS based maintenance methods and IoT. RAMS centered maintenance provides powerful rules for deciding whether a failure management policy is technically appropriate, for providing precise criteria for deciding how often routine tasks should be carried out. It will lead to the improved cost effectiveness, sustainability, and maintainability of railway maintenance system since staff do not have to visit installation sites frequently.

Our paper presented a framework for simulation of IoT based CBM (condition based monitoring) for rolling stocks. This will helps to understand key decisions and principles to analyse the benefit of IoT. Our methodology showed that

prediction, resolution, and gain metrics were generally useful to evaluate RAMS management on day to day operations.

However, this paper has limitations that the data are collected from references, not actual data; the detailed descriptions of IoT application to the railway rolling stocks are omitted, and how RAMS indicators are improved through the suggested reliability centered maintenance are not dealt in detail.

ACKNOWLEDGMENTS

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Developing a Framework for Future Mobile Data Pricing

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ABSTRACT

Purpose: The revenues for mobile data transmission overtook the revenue of voice calls for the first time in 2014 in the USA. It can be observed that demand for mobile data – largely driven by video and cloud - is increasing exponentially, while overall data revenue is rising only moderately. This will lead to insufficient revenues stream to increase investments into mobile networks and ensure quality service. Consequently, hereof network performance will deteriorate sharply. At the heart of the problem is the current global pricing regime of fixed multiple MB/GB bundles, irrespective of time of the day, intensity of usage (e.g. video vs. email) and underlying economic value of the data. A new framework is proposed as to optimize and align network capacity and implicit data value/utility, which is crucial to ensure customer satisfaction and access justice.

Methodology/Approach: The fundamental differences in pricing voice and data in voice and/or data centric networks are analysed in detail. Information has been synthesized as to develop insights into the impact of different devises and type of digital traffic for the overall performance of mobile networks. Based hereupon, a new framework for mobile data has been proposed to address the increasing misalignment between network capacity, usage and underlying data value/utility. Initial solutions have been proposed and discussed.

Findings: While voice calls are easily quantifiable and are largely predictable in its occurrence and network load implications, mobile data traffic shows very large variations depending on type of traffic. While social media messaging by many customers consumes very little capacity, consumption of video streaming by relatively few customers can lead already to network saturation.

Research Limitation/implication: Carriers set prices for a fixed amount of data – irrespective of intensity and time of data traffic - which leads to sharp spiky type of traffic patterns essentially signalling sharp overuse during busy hours coexist with large period of underused times.

Originality/Value of paper: A new framework for proposition building and particularly pricing of mobile data services is provided.

Category: Research paper

Keywords: mobile cellular networks; spectrum; pricing; utilization of mobile networks; economic value

1 INTRODUCTION

Since 2014 US mobile carriers will earn more revenues with mobile data than with mobile voice services. Since voice has been the key revenue driver for mobile carriers during the last 15 years, little price sophistication can be observed as of today, in the data space. In fact, most carriers use data as an add-on to voice. However, given the fact that the industry will eventually evolve towards 100% mobile data, a new framework for mobile data is required.

There are numerous complexities involved is developing such a new framework. There is a huge discrepancy between cost of providing mobile data capacity and revenue generation potential, if compared to voice services. As will be shown this leads to vast variations in pricing data.

The paper will systematically explain the differences between the voice and data centric world and systematically develops a new framework for pricing data services in order to increase data revenues to mobile carriers. This paper starts out by providing a basic understanding of the cost of building and operating networks. Based hereupon, differences between pricing mobile voice and mobile data as well as pricing fixed data and mobile data services are explained in detail. Following, mobile data services are segmented and the challenges between network capex, quality of service and value to the customer are explored. Finally, a new framework for proposition building and particular pricing of mobile data services is provided.

2 FUNDAMENTAL CONCEPT OF CELLULAR NETWORKS

2.1 The Cellular Radio Concept

The concept of cellular mobile telephony essentially evolved around the need to make more efficient use of the radio spectrum in order to accommodate a rapidly growing number of users for mobile services. In contrast to mobile radio systems, mobile telephone services differ as far as they are operating in full duplex- mode and are always connected to the public switched network.

The first commercial mobile telephone service in the United States was established in 1946 in St. Louis, Missouri (Steinbock, 2005). These so called pre-cellular mobile telephone systems used a wide-area architecture: one very powerful transmitter provided coverage of 40-50 miles around the base station,

which was normally located in the centre of a metropolitan area. However, this system design had great limitation in terms of capacity, since only very few channels were available to serve the mobile communications needs of an entire city. In 1976, for example, Bell Mobile provided 12 channels for the entire metropolitan area of New York (more than 20 million people) to serve 543 customers, with an additional 3700 on the waiting list (Lee, 1976). In 1947, engineers at Bell Laboratories devised the concept of cellular radio (Calhoun, 1988). Rather than setting up a high-power transmitter to cover a large area (40-50 miles in diameter) the cellular concept proposed to divide the coverage zone into smaller sections, or "cells," each served by a low-power transmitter. By reducing the coverage areas and establishing a large number of small cells, it became possible to reuse the frequency and thus substantially enhance the capacity of the system.

The fact that the cell radius is determined by the transmitted power, and is therefore variable, enables the systems engineer to continuously decrease the cell size, and consequently, increase the system capacity. Specifically, a reduction in cell radius by 50% leads to a quadrupling of the number of circuits per MHz.

Hence, there are two fundamental ways to increase the overall capacity of a cellular system: first splitting cells into ever smaller sub cells as depicted in Fig. 1 and second adding channels, which in turn requires more spectrum.

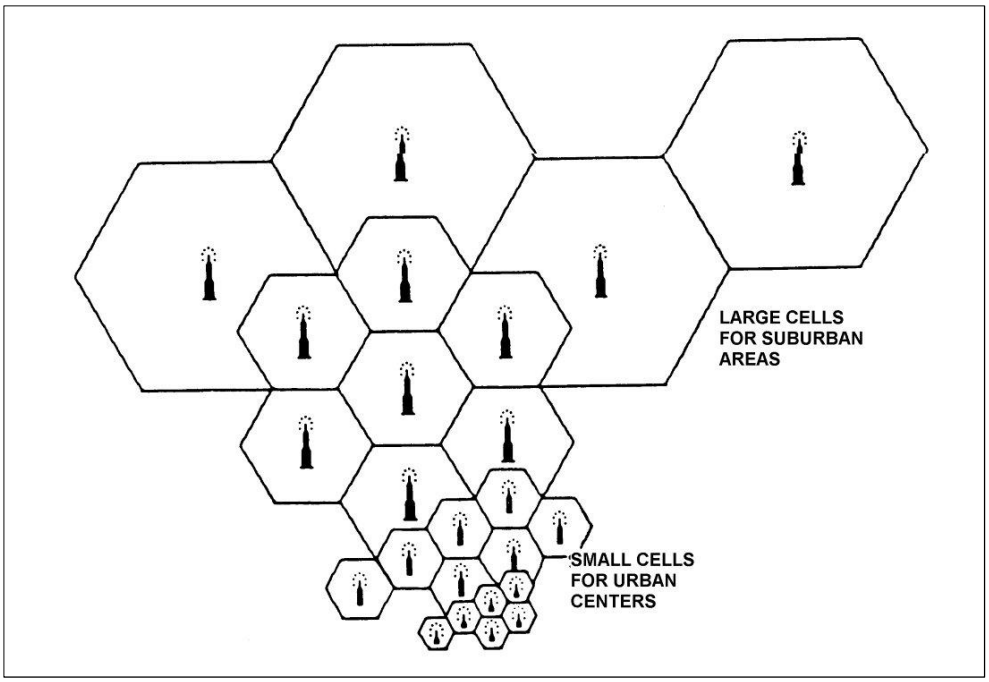

Figure 1 – Cell Splitting (Calhoun, 1988)

It is important to note that cell splitting is associated with high capital cost. Each cell site requires the purchase of a base station and requires costly connection to a

mobile switch by means of fixed leased line or microwaves. In addition, cell sites require maintenance and above all monthly rent should be paid for the site. Hence, spectrum allocated to operate mobile networks play a central role in the overall economics of a mobile system, as will be further outlined below.

2.2 Spectrum and Spectrum Management

All radio communication systems make use of the electromagnetic spectrum. This spectrum is described as "a form of oscillating electrical and magnetic energy capable of traversing space without the benefits of physical interconnection" (Levin, 1971). Although it appears in theory that the radio spectrum is infinite, there are technical and natural reasons that greatly limit the amount of electromagnetic spectrum suitable for mobile communications systems (Seybold, 2005). Hence, radio spectrum is a very precious, highly contested "limited natural resource" and must therefore be utilized as efficiently as possible. The history of spectrum management bears some resemblance to the development of the automobile: At the beginning of the 20th century, only a few cars used the then-available streets, which in turn meant that a driver could practically use the entire road.

With the growing popularity of cars, it soon became obvious that traffic rules would have to be introduced to avoid accidents, as well as to increase traffic flow (serious impairment of movement). In a similar way, everybody could make use of the US spectrum, prior to 1927, by simply writing a letter to the State Department of his or her attention to utilize a certain part of the radio spectrum. Over time, however, it became clear that the radio spectrum can suffer from congestion (i.e. interference and service degradation) if too many systems transmit and receive information on it in an uncoordinated way. Therefore, radio spectrum had to be systematically organized on national level, and – since electromagnetic waves in the low frequency bands do not stop at national levels – also internationally.

Developments in mobile communications systems are largely driven by the availability and/or scarcity of spectrum. Since radio waves with different frequencies have very dissimilar propagation characteristics, certain parts of the radio spectrum are far more suitable for land-mobile-communications systems than others (Seybold, 2005). With large parts of the highly usable radio spectrum virtually completely allocated, the growing demand of both existing and new mobile communications services can ceteris paribus only be accommodated by replacing current systems with more spectrum efficient ones, or by the development and introduction of technologies that will allow certain mobile communications systems to economically operate in higher frequency bands that are less crowded.

2.3 Advances in Cellular Technology

It is important to understand that cellular mobile communications were initially seen as an add-on, and very elite service to the existing fixed switched network. The first US analog commercial networks based on the AMPS standard (so called 1G), grew from less than 100.000 subscribers in 1983 to more than 10 million subscribers in 1992. As depicted in Fig. 2, the growth rate has been in been indeed exponentially. It became obvious that an analog system could not cope with this kind of market development.

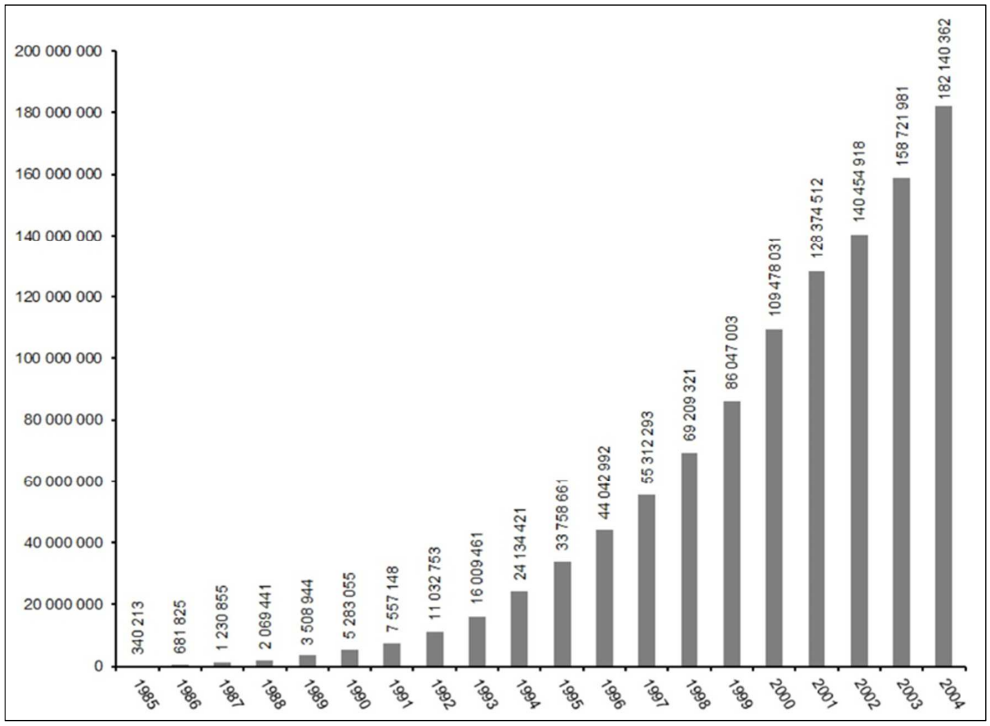

Figure 2 – Year End 2004 Estimated Wireless Subscribers (CTIA, 2005)

This marked the advent of two important developments: first, it became clear that the network technology has to evolve from analog to digital. The work for the first digital network (GSM or 2G) started in the mid-80s and was launched commercially in the 900 MHz band in 1991 (Pelkmans, 2001). The second important impulse stemmed from the insight that instead of a luxury product for a few, mobile communication will become a mass product eventually superseding fixed telephony. This idea was captured in the term "Personal Communication System (PCS)" or "Personal Communication Network (PCN)" (Paetsch, 1993). In the mid-90s, it became apparent that the data rates offered, were too low for fledging data market. Work on the so called UMTS or 3G network started, and the first 3G network was launched in 2001. This network is designed to accommodate data and voice traffic equally.

However, by the turn of the century it became clear that the unbelievable growth in the internet will eventually have to be supported by mobile networks and work on LTE, respectively 4G networks, started (White Paper, 2011). LTE is clearly a network designed to efficiently handle mobile data only (White Paper, 2011). Voice and Data traffic are all IP in a 4G network.

Fig. 3 summarizes the development of mobile communication: almost exactly every 10 years a new cellular technology was introduced into the market, operating on higher frequencies spectrum and featuring ever smaller cells size radiuses. Hence, the amount of base stations required to provide coverage is increasing sharply. This problem gets further aggravated by the fact that 3G and 4G cells are shrinking as the "load" i.e. capacity of a cell gets filled with traffic (Portilla-Figueras, et al., 2009).

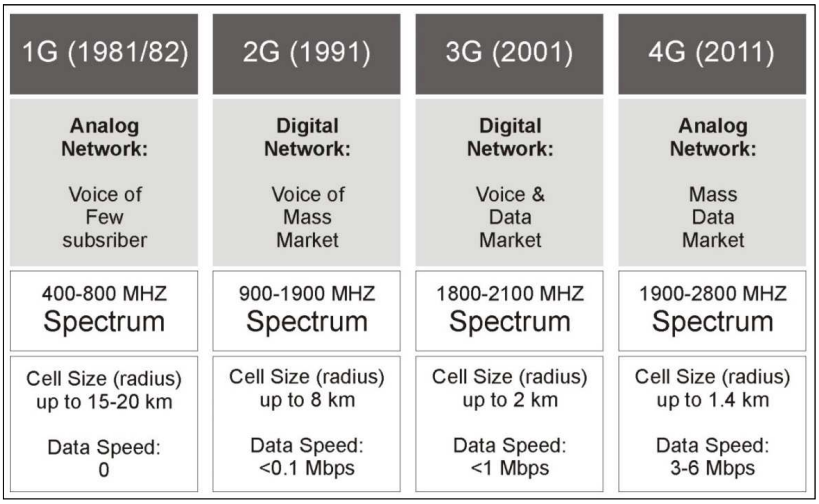

Figure 3 – The Development of Mobile Communication (Paetsch, 1993)

Especially is these areas substantial differences exist between the voice centric 2G and the data centric 3G/4G network economics. These differences will be discussed further below. The following Fig. 4 shows how the global subscriber base is currently connected towards the different network technologies.

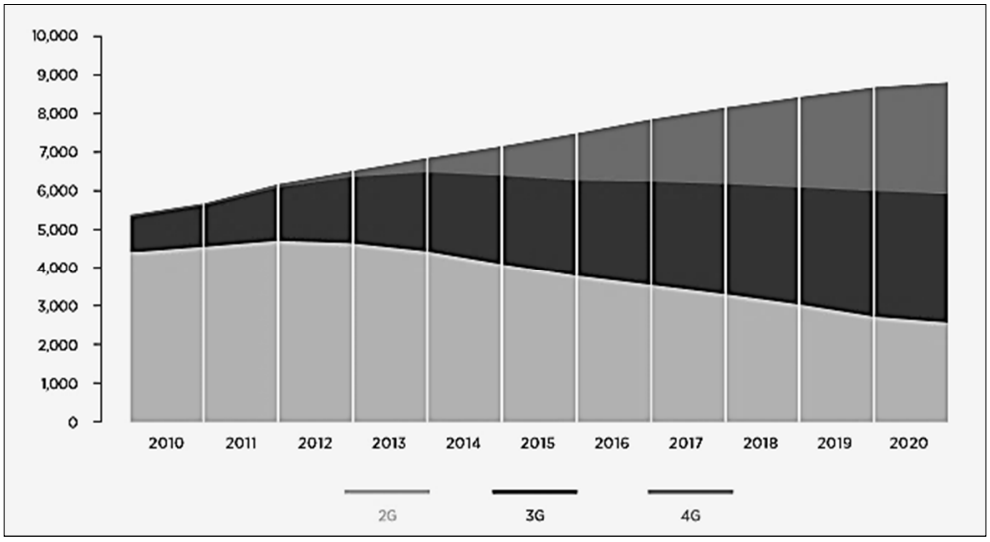

Figure 4 – Global Subscriber Connections in Mio. – Excluding M2M (GSMA, 2016)

3 EVOLUTION OF USAGE PATTERNS

As pointed out above, the first twenty years of mobile communications were clearly dominated by providing voice traffic. Fig. 5 shows how mobile data will surpass mobile voice globally. According to GSMA report (GSMA, 2013), the mobile operator data revenues will overtake voice revenues globally by 2018 as we move towards a fully connected world.

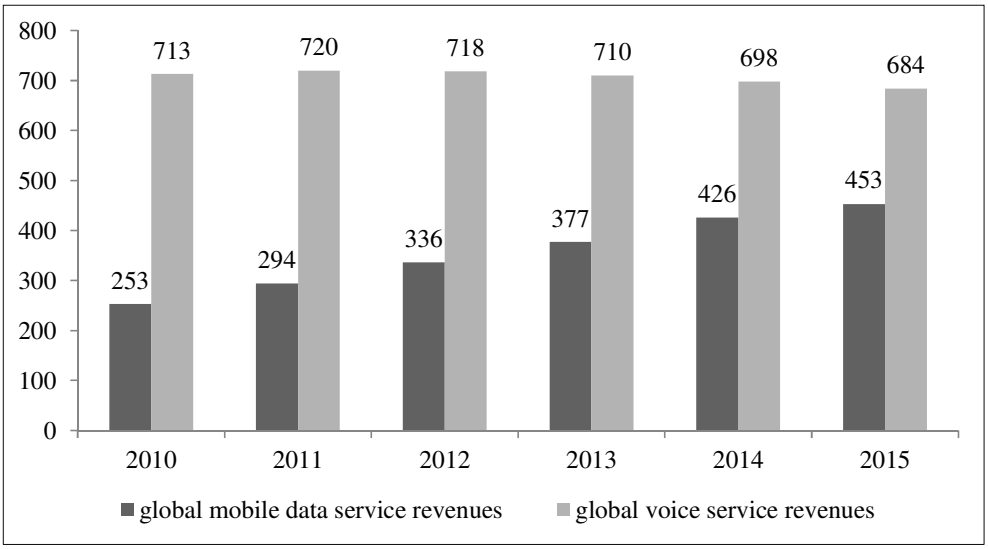

Figure 5 – Voice vs. Data Revenue 2010-2015 in Billion U.S. Dollars (Statista, 2017a; 2017b)

There are two three major factors driving the consumption of data usage, leading to a situation in which data ARPU (average revenue per customer) exceeds voice ARPU: reduction in voice related pricing, the strong rise of "on-the go computing" devices and migration of a largely fixed internet business model to an "anytime-anywhere" internet model

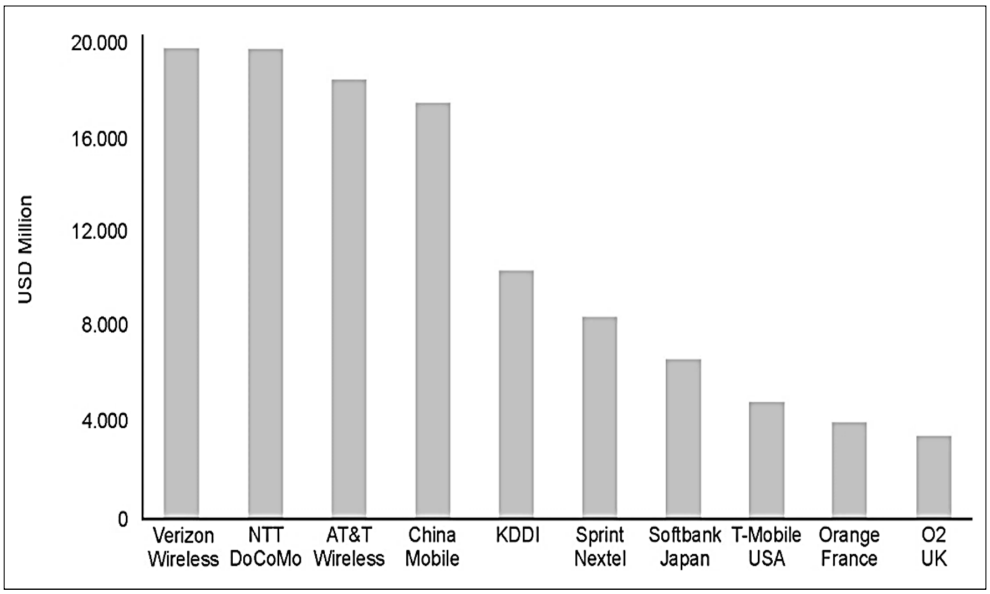

Figure 6 – Data Revenues in Billion U.S. Dollars as of Q4/11 (Sharma, 2012a) (Note: Verizon & ATT are US Telcos, NTT and KDDI and Softbank are Japanese Carriers)

In the US, this inflection point – i.e. the crossover of mobile data exceeding mobile voice revenues – occurred in 2013. Aside from Japan, the US is the leading nation with regard to overall voice revenues as shown in Fig. 6.

3.1 The Pricing of Mobile Voice

During the early stages of mobile cellular networks, pricing of voice services was straight forward but expensive. Most mobile networks adopted a peak/off-peak pricing scheme. This provided an adequate pricing mechanism, given the fact that the networks especially in the metropolitan areas had only a limited number of channels available. As early adopters were largely professionals with very little price sensitivity, pricing during the day was extremely high, respectively low during the off-peak time. Switching between off-peak/and peak occurred around 6 pm. The peak pricing would reflect the given capacity at the time of network rollout. With the beginning of mobile personal communication, i.e. the evolution of a mass market in mobile communication, the situation changed fundamentally. The handset prices fell dramatically and as a result, diffusion of mobile phones increased substantially. However, these new added customers had a very different usage pattern. Since these early nonprofessional consumers were

much more price sensitive, the traffic pattern changed fundamentally. As described in Fig. 7 indicated by the black line, early network traffic was clearly reaching the highest level during peak hours and slowed down considerable during off-peak hours. As more consumers were added to the network and at the same time capacity of the network was enhanced, the curve developed into a pattern reflected by the dark grey line in Fig. 7. The higher price sensitivity of these consumers coupled with the high difference between peak and off peak traffic (up to factor 5), lead to a traffic abnormality. As described by the grey line in Fig. 7, consumers virtually sharply decreased mobile phone traffic prior to the peak/off-peak border and "postponed" calls to the past peak time. This resulted in an extremely high traffic peak right after the switching time, often exceeding the capacity levels and therefore negatively influencing customer satisfaction (Khanfir and Fitkov-Norris, 2000; Yaipairoj and Harmantzis, 2004).

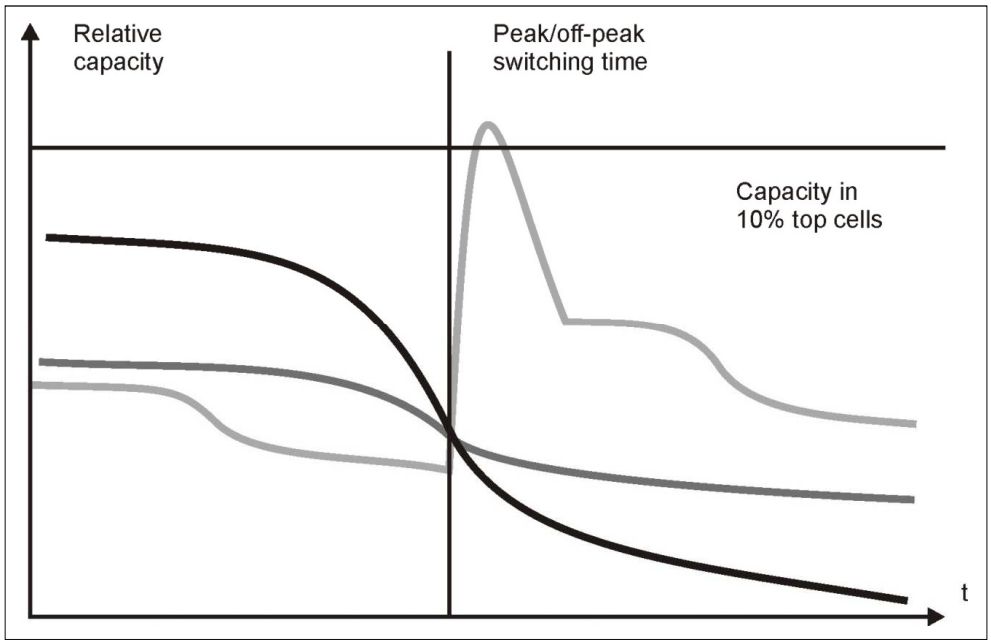

Figure 7 – Systematic Overview: Network Load in peak/off-peak Pricing Scenario over Time

This in turn forced the mobile operators increasingly to expand capacity to meet off-peak traffic. As a consequence many ways of pricing network capacity in order to maximize revenues were discussed (Basar and Srikant, 2002; Fitkov-Norris, 2003; Baochun, Nahrstedt and Xue, 2006). In most European countries, however, most mobile operators adopted a non-dynamic pricing scheme which is far easier to communicate to consumers, known as airtime bundles. A typical airtime bundle comprises a given number of minutes for a fixed price. A larger airtime bundle would offer a lower minute price than a lower airtime bundle. The consumers could use these airtime bundles around the clock, the concept of

peak/off-peak disappeared. This tariff structure represented a fundamental shift toward a much more pro-usage scenario (i.e. personal communication) and marked the beginning of the direct attack to substitute rather than amend the fixed network (Vogelsang, 2010). The bundling airtime pricing had furthermore the advantage to appear much more attractive to consumers than it really was. This is described in Fig. 8. If a consumer purchases a certain airtime bundle B (e.g., 50 minutes) for a certain price P (e.g., 20 EUR), he or she will focus on a certain price per minute (PpM).

In fact, the consumer will automatically calculate P/B thereby inevitable calculating the lowest possible average price per minute possible (0.40 EUR), market in the Fig. 8 a yellow dot (0.40 EUR per one minute). Interestingly, it is practically impossible for the consumer to reach exactly this point in the course of one month. If for example, the consumer was on vacation and used only 50% of his airtime in a given month, the true cost for the average price of a used minute is increasing sharply (e.g., 0.80 EUR). Likewise, prices for minutes exceeding the bundle are substantially higher, thereby also driving up the average cost per used minute substantially. While the consumer liked the easiness and transparency of the tariff, he systematically misjudged the true PpM cost.

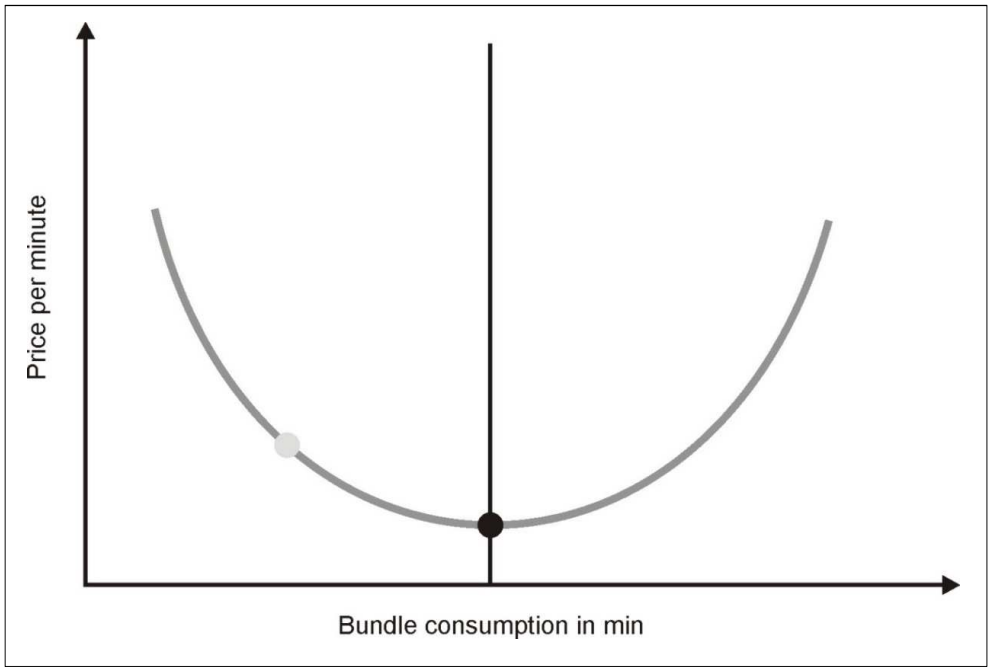

Figure 8 – Systematic Overview: Average Airtime Price per Minute in an Airtime Bundling Pricing Concept

In light of the ever larger built-up of network capacity of 2G/3G, the pricing schemes eventually changed to the most aggressive form: flat pricing for fixed network and eventually fixed and mobile telephony. This pricing scheme was

adopted first in 2007 in the USA and is experiencing widespread adoption. As Fig. 9 indicates this flat pricing scheme did not only increase the used minutes per user and progressively lowered the cost per consumed minute but also lead to a rising number of consumers that terminated their fixed access completely (Rodini, Ward and Woroch, 2003). This effect is known as fixed-to-mobile substitution and is an accelerating trend in advanced mobile markets with a dense fixed network infrastructure such as Europe and the USA (Banerjee and Ros, 2004; Albon, 2006).

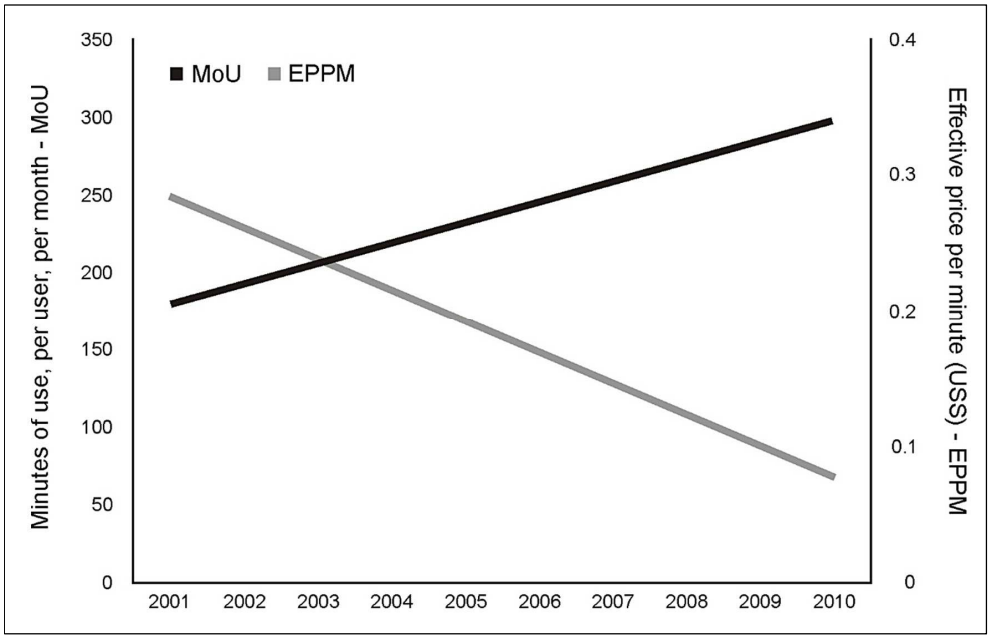

Figure 9 – Development of Use and Effective Pricing of Mobile Switched Minutes 2001-2010 Globally (Note: MoU user per month, EPPM Worldwide effective price per minute) (Wireless Intelligence, 2012)

3.2 On the Go Computing

Aside from the sharply falling effective prices for mobile minutes, the appearance of on-the go computing devices such as smartphones and tablets greatly influences the change in usage pattern away from voice towards data (Specifically, the launch of the first iPhone allowed for the first-time mobile web browsing on an acceptable level).

For years, the existing mobile phone technology and form & design function proved unsuccessful of accelerating mobile internet usage. As Fig. 10 demonstrates, this only changed with launch of the iPhone. The iPhone had a market share of only 11% in 2009 but was responsible for over 65% of all web request in mobile networks. The world market leader (Symbian) on the other hand had 49% installed base in the networks, but only 7% of the total mobile web sites were requested by this phone. The on-the-go computing devices will

transform the IT ecosystem only comparable with the transformation from mainframe to PC. As indicated in Fig. 10, the growth in IT hardware is clearly moving away from traditional desktop and laptop devices towards smartphones and tablets.

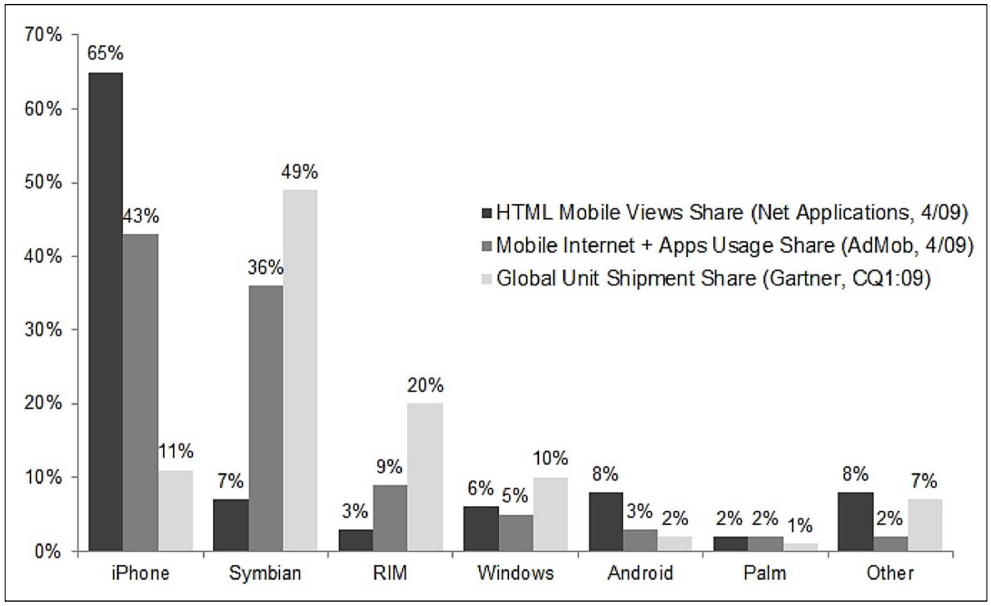

Figure 10 – Web Usage vs. Operating System (Gartner Group, 2009)

In contrast to traditional IT hardware, are on-the-go computer devices not only highly mobile and a have long battery life, but can be switched on or off in seconds.

3.3 Mobile Internet

Especially the trend toward on-the-go computing described above, lead to an explosion of network data traffic. In fact, it can be argued that the desire for customers to access the internet has been already building up steadily, but was effectively suppressed by the non-availability of adequate hardware. Hence, a de facto market vacuum was building up, which in turn led the iPhone to become the device with the fastest ever recorded diffusion speed. This becomes evident when studying Fig. 11. While 3G network were launched already in 2001, only a very slow data growth could be observed until 2007 (Phase A). As pointed out in Fig. 12, available equipment in Phase A did not entice consumers to make use of the mobile internet. This changed fundamentally with the introduction of fully screen phone with touch sensitive screens.

Another invention fuelling the use of mobile data were the so-called Apps. Apps are small native applications, which are easy to download and use on a smart phone. Around these apps, a whole new ecosystem comprising millions of applications developed in only a few years. These apps are perfectly suited for operating in a mobile environment: since these small program is residing on the smart phone itself, only data for refreshing information had to be transported, providing consumers with a very good user experience (Kessler, 2012).

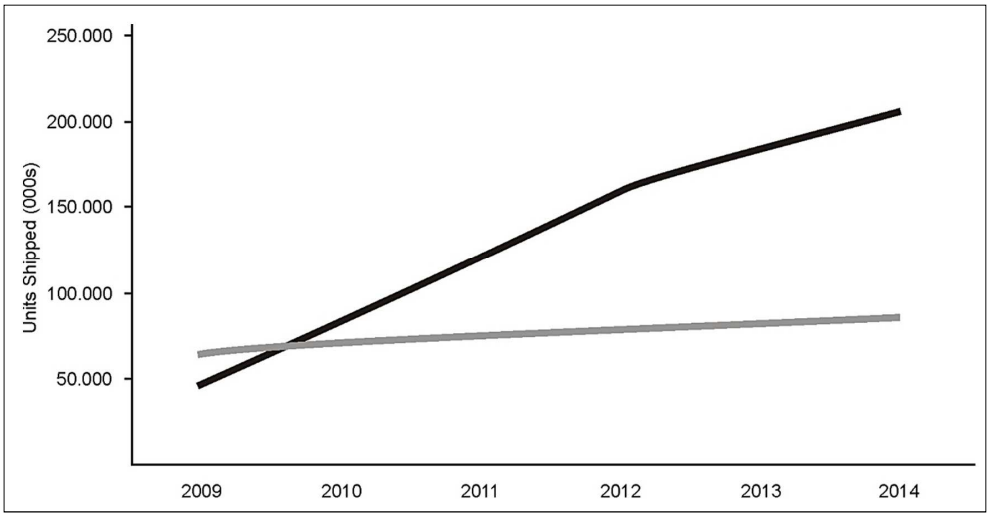

Figure 11 – Development of Desktop/Laptop Shipements (grey line) vs. Smartphones/Tablets (black line) 2009 to 2014 (Sharma, 2012b)

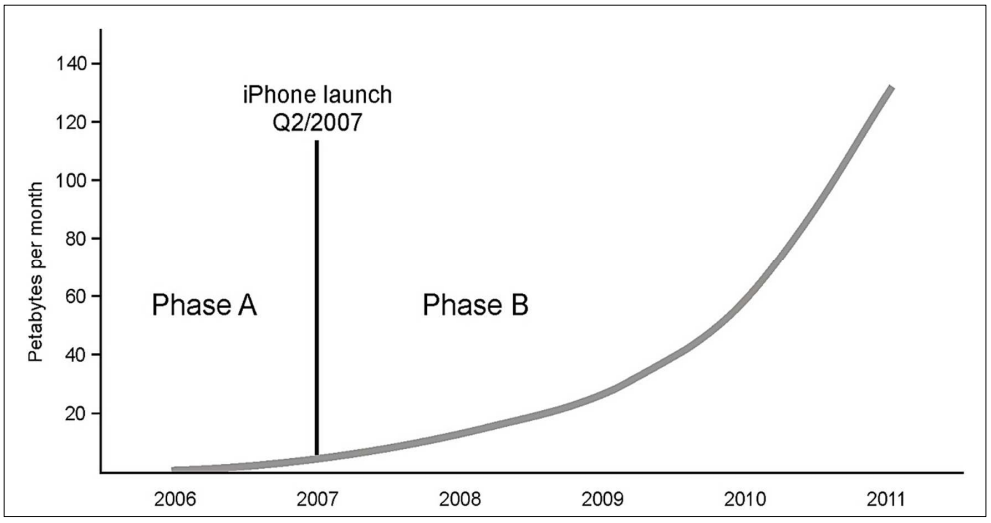

Figure 12 – US Mobile Data Growth 2006-2011 (Sharma, 2012c)

In summary, it becomes clear that the usage pattern of mobile communications services is shifting dramatically towards mobile data away from mobile voice. While mobile data has so far been viewed, and priced as an appendix to voice, this development will require telcos to fundamentally review data pricing on its own. As outlined in the following chapter 4, pricing data is a highly complex undertaking requiring a new approach and a new framework.

3.4 Data Usage and Data Pricing and Data Revenue

The above described massive shift from voice centric mobile phones to smartphones is accompanied by a parallel trend towards digital media. While email and chat clients do not consume a lot of network capacity the opposite is true for data intensive video streaming. Large part of the network capacity is used over relatively long periods of time. The strong trend towards usage intensive applications such as video and browsing continuous has reached almost 75% of total data traffic in certain European networks (GSMA, 2014). Consequently, the demand for data is growing rapidly and will reach 22GB per mobile subscriber in the USA and 12 GB in Europe in the USA (GSMA, 2016).

As can be seen from the following Fig. 13, there is fundamental mismatch between the accelerating demand for data on one hand and the monetization potential or revenue on the other hand.

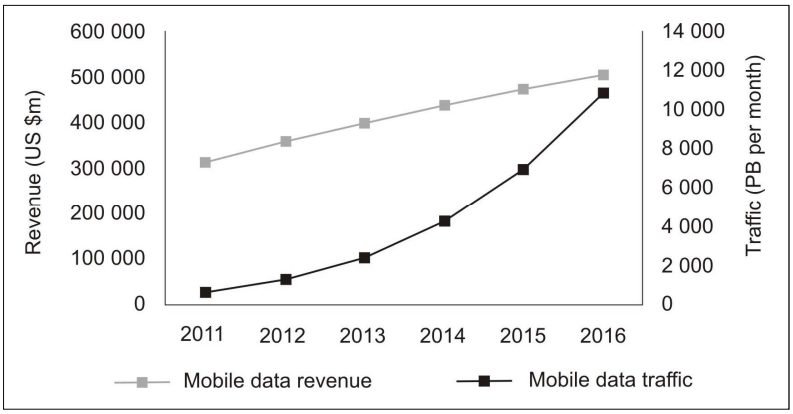

Figure 13 – Development of Mobile Data Revenue and Mobile Data Traffic (Ernst & Young, 2013)

It becomes obvious that there is a fundamental mismatch between data consumption and data revenue, which will lead to a situation in which telco carriers cannot invest sufficiently into their networks to sustain the strongly rising traffic. Under the current data pricing regime and in the absence of any new intelligent data pricing strategy this will lead to highly congested networks very similar to rush hour traffic in metropolitans. Overall, this appears not a viable long term strategy, given the importance of mobile data networks for the economy especially when moving into a cloud centric macro IT architecture.

4 A NEW FRAMEWORK FOR DATA PRICING

4.1 Key Differences between Voice and Data Pricing

In order to understand the principle differences of voice and data pricing, above outlined characteristics of 2G and 3G/4G networks play a crucial role. Below, the key differences of voice and data centric networks are grouped and subsequently outlined.

Cell Scale vs. capex in a voice centric vs. data centric network: The cell size of a 2 G can be more than 20 km. Importantly, the cell size is fixed and therefore the capacity in a given cell accurately predictable. Only if capacity demand is increasing and/or in-house coverage should be improved, cell splitting is performed. This means that capital outflow is - apart from the initial investment – very much in sync with rising number of customers and usage.

In data, centric network, this is fundamentally different. As pointed out, 3G cells do not have a fixed cell size. Rather the radius of the cell is shrinking when the cell gets loaded with traffic, thereby making it necessary to add cells for coverage under load. Another substantial difference is the cell radius itself. While 2G cells can be around 20 Km 3G/4G cells have a maximum cell size of only 1 to 1.5 km. This means, however, that the "capex-characteristic" differs in the sense that much more cells along with back link facilities, rent, maintenance, etc. have to be installed right in the beginning. Moreover, given the much smaller cell radius, the cell does not provide capacity scale to a large area, but rather a very small area. So, it is perfectly possible that one 3G/4G cell is fully loaded leading to blocking, while the other one is practically empty.

One device provisioning in voice networks vs. multi-device provisioning in data networks: In the previous decades, mobile communications centred essentially around the provision of voice services. Hence, voice represents an on-off type of service, occupying always exactly the same load/capacity from a cell. This is again fundamentally different in a data centric network for a variety of reasons. First, as outlined below in Fig. 14, data networks are accessed by a large variety of hardware ranging from smartphones, tablets to laptops, etc. The consumption of bandwidth for each device varies greatly if averaged over the month.

This has several important implications: a voice centric network handled only voice calls via one device, allowing very accurate prediction of traffic load. The capacity load of data network can vary greatly, depending on the observed mix of devices in the cell at a given time.

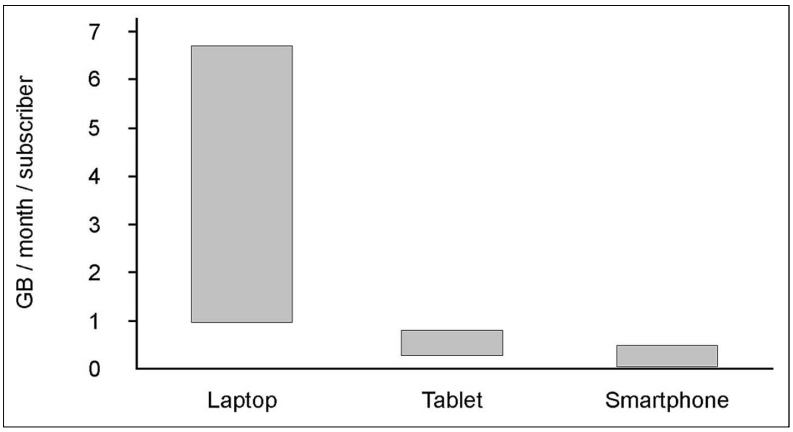

Figure 14 – Monthly Traffic Volumes in 3G by Type of Equipment (Malik, 2012)

One service provisioning in voice networks vs. multi-service provisioning in data networks: aside from the complexity regarding multiple equipment with different capacity demands, services provided in voice and data network differ equally large. Historically, a voice network provides only one service and this is voice.

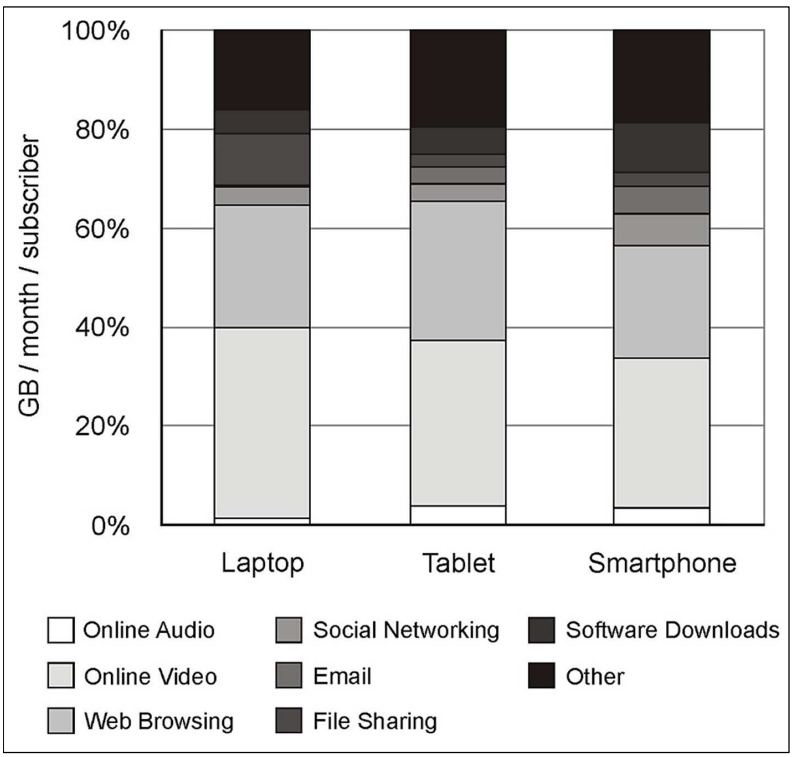

Figure 15 – Overview of Various Services Used by Different Equipment (Malik, 2012)

The capacity of one voice call is always identical and it therefore easy to quantify the capacity. This contrasts sharply in a data centric world. It is very important to cluster the different types of traffic (Fig. 15). Online services such as online audio and only video are called real-time services, for the application cannot tolerate transmission delays without the customer experiencing a sharp and instantly noticeable drop in quality or even usability.

Services like web browsing, social networking, email, file sharing and software downloads are so called non-real time services. Small delays or a certain deterioration in transmission speed increases the waiting time of the consumer but does not render the service useless. The by far fastest growing type of services in data networks are the real time streaming services for music and video (Youtube, Napster, Somify are only a few of well-known streaming platforms). However, it should be mentioned that streaming absorbs high rates of capacity measured in Mbps.

Quality of service in a voice centric vs. data centric network: measuring quality in a voice centric network is very easy and transparent. A customer can either receive/make a voice call or not. A situation in which a voice call cannot be completed is referred to as blocking. Quality is therefore easily measurable by the blocking rate of each cell at the busy hour of the day. In a data centric network, quality is much harder to define, measure and ensure. Given the fact that the cell size is much smaller, and the multitude of devices and real-time (RT) non-real time (NRT) traffic can vary widely, traffic throughput and especially service degradation can vary sharply.

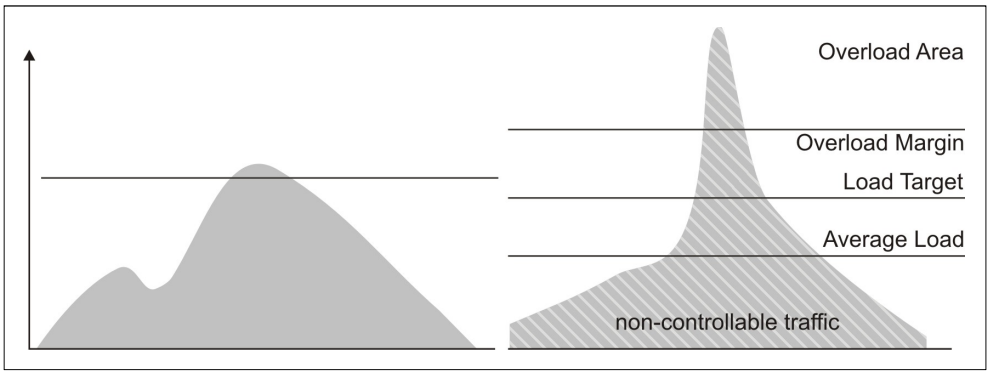

Figure 16 – Peak Shaped Traffic in Voice and Data Centric Networks

In summary, a voice network comprises larger cell sizes that are used by only one device producing one type of service, i.e. voice. The criteria for quality (i.e. blocking rate) is transparent and easy to measure. In sharp contrast, hereto, peaks in data centric networks are much more pronounced and statistically or mathematically far less predictable. First, the cell size is substantially smaller in coverage size and second different devices accessing different type of traffic require a widely fluctuating capacity at a given time. It is important to note that

very steep narrow peaks represent a twofold problem. They either lead to blocking of real-time traffic which directly negatively impact customer satisfaction (Lee, 2010) (overload area Fig. 16), or they require very high capex to meet peak capacity needs, which, however, is utilized only for a very short time. This in turn provides an extreme low payback for a given investment.

4.2 Current Data Pricing Concepts

As demonstrated in Fig. 12, early mobile data uptake between 2001 and 2007 has been extremely low. It has been established that the key reason therefore was not so much the pricing of mobile data but the lack of suitable hardware. It has been further documented that the launch of 3G coincided with the trend towards pricing voice services flat. These two factors were instrumental for the fact that a variety of countries (e.g., US) offered unlimited usage or very high data bundles (5 GB) for a relative low price. Given the small size of 3G cells, the initial capacity of the network was quite high and usage very low. Hence, the under-pricing of data had no capex effect. This changed dramatically in 2007.

With the smartphone becoming popular, growth in mobile data grew exponentially as shown in Fig. 12. Over time, another phenomenon became apparent: very few extreme heavy users consumed a large part of the bandwidth. As described above, the US is the leading mobile data market. Interestingly, it was the number one smartphone carrier AT&T, which experienced severe service problems in its metropolitan area first. Fig. 17 describes systematically the impact of blocking. Most users consider the non-real time services such as accessing the email or social media sites or general websites as much more important as streaming a YouTube video. As will be shown later, they are also willing to pay much more money per Mb for these services than video streaming. However, in a flat data or excess data bundled pricing scheme, consumers will make abundant use of streaming. Since streaming is real-time traffic, it will be prioritized for any delay leads to an almost total loss of quality.

After the initial capacity of a given 3G cell (load target) was reached, the cell has zero capacity for sending the non real-time traffic (email, etc. dark grey area in Fig. 17), which actually is more valuable to consumers. Eventually, with more consumers engaged in streaming, the cell would become overloaded providing no streaming satisfactory streaming service whatsoever. One remedy against overloading networks is the so called throttling policy: the top x% of users would be sharply reduced to 2G data speed for the following month, respectively their access speed was lowered when they reached the end of their bundles. Since this does not provide immediate network capacity relief, AT&T, for example, started to remove the heaviest mobile data network users under the flat pricing scheme. In fact, AT&T claims that 2% of its top user accounted for 60% of the traffic.

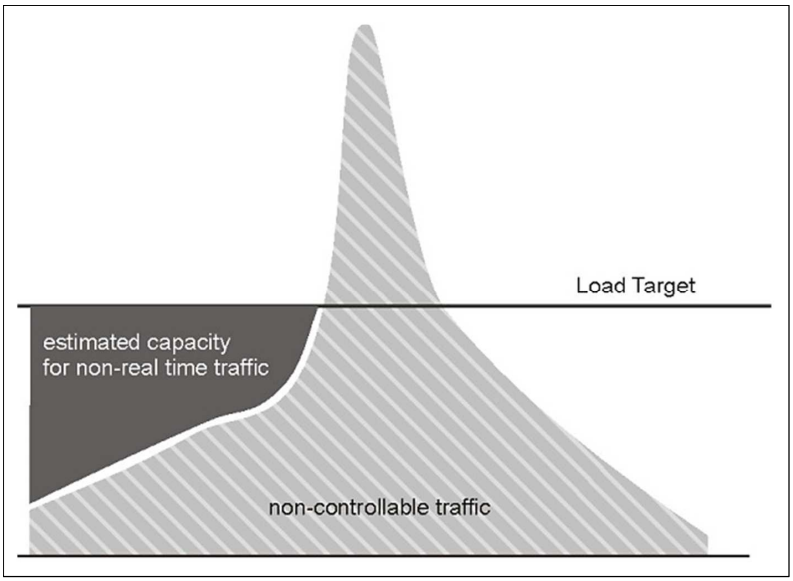

Figure 17 – The Relationship between Real-Time (non-controllable) and non-Real Rime Traffic and Load Target

4.3 Towards a New Mobile Data Framework

It is clear that the throttling down policy cannot meet the conceptual challenge posed by network loading in the medium to long term future. Other mechanism must be found to ensure good network quality and access justice (Zhao, et al., 2012). A fundamentally new concept is needed to balance the capacity and device and type of service. The pricing should be balanced as to be acceptable to the consumer on the one hand and allowing the carriers to recoup its investment on the other hand.

The logical evolution of such a pricing framework is described below and must comprise static and dynamic pricing elements:

Tariff structure and device segmentation: clearly mobile data pricing has to become a function of the characteristics of the device with clear distinction between smartphone/tablets and laptops.

Ensuring high quality basic service: In order to ensure good quality service for smartphone users, carriers must focus on guaranteeing high quality non-real-time services (dark grey area in Fig. 17). Hence, a new pricing framework must clearly perform price segmentation between RT and NRT traffic.

Regain control over network load by reducing data bundle size greatly: As a consequence on these two demands, carriers will have to reduce bundle size sharply to the average usage of smartphones (Zheng, et al., 2015). A smartphone uses about 350 MB per month, while a tablet requires about 1 GB per month. Furthermore, they will have to raise prices. Bundle size must be sufficient to

allow for only very occasional streaming. Even the largest bundle size should not facilitate unrestricted use of streaming. As shown in Fig. 18, the countries such as Japan and the USA feature already much higher data prices to get network capacity in line with demand.

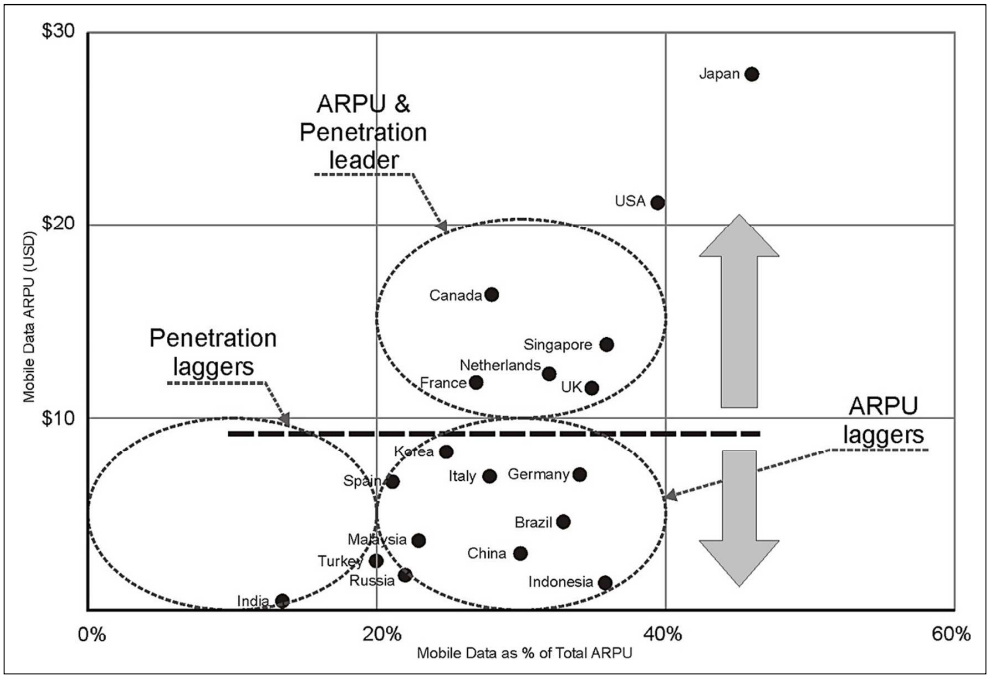

Figure 18 – Mobile Data ARPU – Absolute and as % of Total ARPU (Sharma, 2012a)

After the initial network load was used (first investment required to achieve 3G coverage), it became clear that the true cost of accommodate mobile data traffic is indeed very high. AT&T and Verizon both introduced small bundles with only 200 MB for smart phones for 15-20$ and a second bundle capped at 2GB. Both carriers stopped selling unlimited packages.

Static versus dynamic pricing elements: Above mentioned small mobile data bundles for smartphone and tablets represent static pricing elements. Since the bundle sizes are small and the traffic characteristic is non-real time centric, a high degree of quality of service and predictability can be achieved.

Dynamic pricing elements: Given what has been established above, it is clear that the load/remaining capacity of a cell can vary hugely according to time are coverage area. While very "light" streaming is facilitated by the data bundles (static pricing element), extreme heavy streaming is prevented. Key streaming applications such as watching a movie, use of Skype or You tube can be controlled by allowing consumers to purchase vertical packages. These vertical mobile packages are priced according to actual or predicted traffic load in the coverage area at the price of purchase (low/medium/high price) to grant access

for a certain time. It is therefore possible that watching a movie on a tablet PC depends on the time of the day.

Sourcing pricing elements: It has been established that video and browsing is currently already accounting for up to 75% in mobile networks. In the future, a large part of the data growth will also stem from cloud based storage and/or applications. This could lead to situations in which at a given busy time in a given area critical business data cannot be accessed readily because the bandwidth is absorbed by streaming of leisure videos. Since both user bundles are priced identically, time, intensity and especially economic value are not priced. Given that increasingly traffic originates from large cloud networks such as more leisure centric clouds like YouTube, Netflix as well as more commercial cloud offerings such as Microsoft, SAP cloud, etc. tariffs could be structured as to allow network carrier to block access to some clouds for a limited time during the day.

Aside there is little doubt that fixed and mobile broadband will eventually compete head on. This kind of "fixed" mobile traffic can accommodate by using two dynamic elements: First fixed-mobile DSL packages are tied only to certain cells outside the metropolitan areas and can be reduced during peak hour by 25% interval steps, transparent to the customer. This is to ensure that the mobile RT and NRT traffic enjoy priority over the fixed mobile traffic.

5 SUMMARY

The paper documented the astounding rise of mobile communications. While mobile voice was thought to be an add-on the fixed switched public network, it eventually eclipsed the fixed telephony service: the vast majority of voice traffic is handled today by the mobile networks. It is clear that mobile data is following the same evolution path. However, it has been pointed out that the characteristics of mobile data are very different compared to voice.

The small cell size and the fact that the capacity of such a cell is not scalable confine available capacity to very small areas. A variety of devices absorbing very different RT/NRT traffic at certain peak times, pose another big challenge that cannot be addressed by static data bundles alone. The problem is further aggravated by the fact that the traffic with the highest demand on network capacity (i.e. streaming) has generally the lowest economic value to user. The paper therefore argued that moving forward, pricing of mobile data services have to comprise static and dynamic elements. Importantly, the pricing scheme has to segment NRT/RT traffic sharply, ensuring that especially the quality of service of NRT traffic meets customer expectation. Occasional or "light" streaming can be performed, but since this data bundles are small, consumer will not engage in extreme streaming activities. The RT traffic is segmented by first introducing vertical bundles (e.g. watching a video at a train station) for specific streaming services priced according to network load and second making specific services

such as “mobile DSL” only available in non-peak coverage areas. Only such a pricing framework appears suitable to address the specific challenges arising from meeting customer needs for high quality reliable service on one hand and control network cost on the other. Further research is needed to understand how various price setting factors that are effective in controlling the described complex network load balancing between various types of devices and content within the network and its impact on price perception, overall customer satisfaction and data usage on part of the consumer.

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Work Standardisation in Logistics Processes

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ABSTRACT

Purpose: The article presents a concept of synergy between MTM (Methods Time Measurement) and TWI (Training within the Industry) methods through a case study conducted on elementary logistics processes. MTM brings optimisation into logistics operations and creates quality and efficiency standards. TWI provides the means of application of these standards at work to drive improvement.

Methodology/Approach: To show a prospective viability/added value of the MTM and TWI combination, we present a case study involving simple logistics processes. We use the MTM as a standardisation method and the TWI as a variability control and process improvement concept.

Findings: The MTM times generally determined as an external regulation, may not reflect the level of skills of workers in a specific company and often create a barrier to internal improvement. The concept of work standardisation based on the MTM method synergised with the TWI creates a dynamic improving system.

Research Limitation/implication: Individual variations in the processes need to be accounted for and the terminology of current optimisation method and improvement concept need to be adapted accordingly in the present analysis. The methods of MTM and TWI employed in our study now slowly penetrate the logistics processes.

Originality/Value of paper: The paper introduces a new approach to the methodology of internal logistics improvement. The MTM work standards increase the stability and productivity in logistics. However, they often hinder the change by allowing for only low degree of flexibility. Combining them with the concept of TWI, we can enhance quality and foster the human potential to change.

Category: Case study

Keywords: MTM; MTM-logistics; TWI - training within the industry; Kaizen

1 INTRODUCTION

Work standardisation is not a new concept. It has been a key factor for industrial evolution since Taylor´s times. Frederik Taylor introduced the idea of Time Studies by observing a job and breaking it down into individual tasks (Taylor, 1967). Work standards enabled a worker to work faster while achieving better quality. Many scientific studies followed with further development of work standardisation and predetermined motion time systems (PMTS). PMTS are work measurement systems based on the analysis of work into basic human motions, classified according to the nature of each motion and the conditions under which the motion is made (Mital, Desai and Mital, 2017). The first PMTS foundation was laid out by the research and development of Frank B. and Lillian M. Gilbreth (Gilbreth, 1912). One of the significant advantages of PMTS is that they require a detailed description of the working method, and are thus useful for studying how work is done, how it can be improved and how much time it should take (Khanna, 2017). In the 1950s Maynard, Stegemerten and Schwab (1948) developed Methods Time Measurement (MTM). The MTM was the first of a series of predetermined motion time systems, predetermined in the sense that estimates of time are not determined in individually, but are derived from an industry standard. The MTM methods are nowadays used in most countries in various industries. This is due to their use in the planning stages and further translated into a standardised performance level (Bures and Pivodova, 2015). The MTM facilitates performance rating and eliminates subjective aspects. It can be used in the planning stages, it offers common work standards in industry, etc. (Chary, 2009). Worker cooperation and compliance are not required, and the workplace is not disrupted. Performance ratings are included in the motion times, eliminating this subjective part of developing standard times.

Development of logistics is driven by the development of the economy and by increasing demands placed on quality and quantity of production and service processes. Logistics services represent the source of competitiveness and enter a competitive relationship within the whole supply chain. Logistics management is part of the supply chain management that plans, implements, and controls the efficient and effective, forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption, to meet customers' requirements (Council of Supply Chain Management Professionals Definitions and Glossary). Trying to understand and meet customer's requirements of quality and price, the companies are forced to find new options how to make profitability sustainable. Therefore, it is necessary to be aware how to improve logistics processes. Internal logistics utilises labour and machine work by the use of technology at different levels of mechanisation and automatization (for example material loading and unloading, transportation, warehousing, unit supply, removal of finished products or component sub-

assemblies). Quality and efficiency of logistics deeply depend on stability and capability of logistics processes. One of the most significant criteria for stability and capability control in logistics is TIME. Logistics processes and operations shall be controlled within the scope of acceptable variability by sustainable flexibility.

2 METHODOLOGY

The presented case study shows the prospectiveness of the MTM (Methods Time Measurement) and the TWI (Training within the Industry) combination in logistics processes. According to Yin, a case study is an effective strategy for exploring "HOW" or "WHY" questions (Yin, 2009). In this research, we establish "HOW" and "WHY" the MTM and the TWI methods can be combined. We use the MTM as an effective standardisation method and the TWI as a variability control and process improvement concept. Our assumption was that the MTM brings optimisation into logistics operations to create the quality and efficiency standard in individual activities and that the TWI provides a way of applying that standard to work to enhance the improvement cycle.

The MTM is one of the major PMTS (Predetermined motion time systems) system, which is actually a group of MTMs operating at different levels and applicable to different types of work. MTM1 is the most detailed level of the family, developed by analysing large numbers of repetitive cycles of manual work (Delmar and Franklin, 1987). MTM1 (basic motion time up 0.5 min) gives values for basic hand or arm motions (reach, move, turn, grasp, position, disengage and release) and set of full body motions. For example, the time taken to "REACH TO" an object is then given by a table based on the kind of "REACH" (the object position) and the distance "TO BE REACHED". MTM1 is suitable for measuring short cycle, highly repetitive work. Users can take advantage of this method, for example short preparation time and international acceptance of predetermined time standards (Szombathyova and Šebo, 2006). Other “members” of the MTM group use description of lower level motions. MTM2 is more suited for longer cycle work when the fine level of decomposition of MTM1 is unnecessary in terms of meeting accuracy requirements. It is usually achieved by combining, statistically averaging, substituting or eliminating certain basic motions (Salvendy, 2001). Apart from the basic motions, MTM2 also consists of motions such as "GET" and "PUT".

MTM3 then uses very low description motions such as "HANDLE". A higher level, such as MTM5, consists of a combination of simple and complex elements. The MTM has a growing importance in the area of internal logistics. The main reason is the need to increase the efficiency and quality of logistics as generally “non-valuated” activities. The evolution of time standardisation in logistics has focused on qualified estimates or empirical data based on history up to the more exact ones - time studies using direct measurement or using a method of predetermined times (Klaus, 2009). Since the founding of the MTM Association,

there has been a long tradition of using the MTM and applying the same to logistics. An MTM data catalogue for transport and storage was established at the request of members of the association already in 1970. In 2003, those data were completely revised and edited to comply with newly adopted strict logistics requirements (Beňo, Hrdinová and Sakál, 2013).

The TWI is an industrial training program used in the USA since WWII, also called the 3 J program. It has three specific "J" components: Job Instruction (JI), Job Methods (JM), and Job Relations (JR). The program is focused on tree core skills: How to train people to do the job correctly (JI). How to improve the way jobs are done (JM). How to handle and prevent relation problems (JR) (Allen, 1919).

After Japan's defeat, the TWI was incorporated into the Japanese country reconstruction program (War Manpower Commission, 1945) and over the following decades, it became an integral part of what is known today as the Japanese Management. Toyota adopted Training within Industry program, and the Job instruction method is mirrored in the principles of Toyota Production System as "Standardised Work". The famous Japanese method of Kaizen (continuous improvement) is based on the second J program - Job method. From the post-war-Japan until nowadays, Kaizen has become one of the most successful management techniques in the world.

Currently, we are witnessing the TWI rebirth since Training within Industry: The Foundation of Lean by Donald Dinero came out in 2005 (Dinero, 2005), followed by Conrad Soltero's book The 7 Kata: Toyota Kata, TWI, and Lean Training in 2012, the famous Mike Rothers's book Toyota Kata in 2009 and other. The rebirth is occurring primarily in the "Lean" community. Many companies are working to be lean, but most fail to achieve Toyota's level of success (Liker, 2004). The answer is the absence of "honest" 3 J approach, as the primordial part of TPM (Toyota production system, nowadays known as "Lean Manufacturing"). TWI provided Toyota with some key skills over those "Lean-seeking" companies that simplify the TPM into the LEAN toolkit without the basic system sense. Lean loses its impact over time and people do not sustain the changes.

3 WORK STANDARDIZATION AND STABILITY IN LOGISTICS

Work standardisation is the main premise for achieving an accurate quality result. Work standard is a term designating a sequence of steps by which identical results can be achieved regarding time, procedure/work technique, product and quality. A certain sequence of steps and rules is accepted by all a new and an old employee alike. The standard becomes a natural part of the process and all abnormalities can be easily identified. Standardisation is an essential part of a viable production (Gopalakrishnan, 2010). Similar processes (working methods) with high duplication occur in logistics in a variety of business areas. Processes

(working methods), of different complexity, are known as standard working methods. The MTM logistics applies to standard processes lasting between 3 and 30 minutes, decomposes them, describes them, assigns rules to them, defines the quantity and finally determines table-based time standards.

The time duration of a manual logistics activity (e.g. repackaging of any material, opening and closing a cardboard cover, labelling, etc.) is determined by an MTM-UAS (Universal Analysing System) system for processes 0.5 min – 3 min. Coding of every single process runs through data card system, which contains a predefined range of activities and operations with relevant allocation code and time value measured in timer units TMU (1 TMU = 0.036 s = 0.0006 min). An example of the data card is shown in Tab. 1.

Table 1 – Example of Coding in MTM-LOGISTICS

Procedural steps for transport – general features		**Code**	**TMU**
		4LT	
Control	Steering lever	**ABH**	18
	Joystick	**ABJ**	10
The code for steering lever can be booked in the form 4LTABH with time value 18 TMU (0.648 s)			

3.1 Standardisation Case – Transport from Receiving Area to Shelves

Time analysis was done in a warehouse run by the Logistics Planning Department. There was a need to analyse 25 repeating processes. Due to lack of space, we shall describe only one warehouse sub-process, with standards given for time reduction and optimisation. We have chosen one of the standard operations that occurs in almost any warehouses.

Before proceeding with an analysis, there was a need to check time listed in actual internal documents. Transport from receiving area requires completion of 4 task:

- Pallet discharge.
- Transport of fully loaded pallet from receiving area to shelves.
- Transport of unloaded pallet in circulation.

Time listed in internal documents for this process was 2.52 min. In spite of the fact that we received data from the company, as well as observed the process in motion, we had to conduct our own time studies to get exact information on the cycle times within the warehouse. The average time after 25 measurements were 2.85 min (Fig. 1).

We analysed the process with real time value, which is in average 0.33 min greater than the time listed in internal documents before primary measuring. The variability of the measured time directs our attention to deeper analysis of the

process. The range of the process is 1.3 min. That means, that current standards are lower than those calculated by the company.

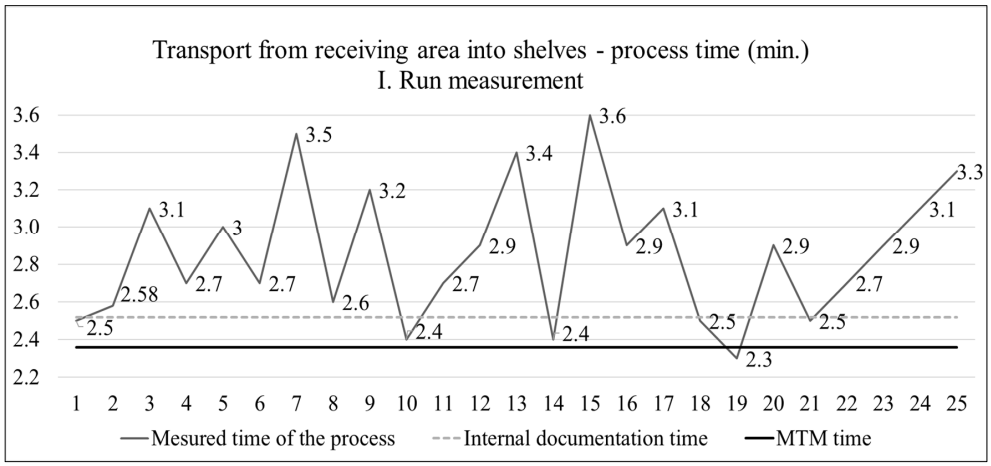


Figure 1 – Transport from Receiving Area into Shelves - Process Time (min)

Carrying out the analysis using the MTM-LOGISTICS method, we discovered more time space and that means a waste of time in individual process sequences (Fig. 2). Total savings of time compared to time presented by actual company standard can differ by 0.16 min, compared to average real time of 0.49 min. After analysing the reasons attributable to time variability, we arrived at the conclusion that the work standard is not implemented in the warehouse, and the work methods are not adjusted to the traffic situation on the warehouse floor. The required MTM time is 2.36 min.

The MTM specifies internationally accepted time of elemental tasks in predicted workflow for a well-trained worker. The questions are:

- How to reach the MTM time as quickly as possible (how many work cycles does it take for a worker to reach the Time standard)?
- Is the MTM time most efficient according to the value of its outcomes and for processing customer needs? Is it possible to use the MTM and to accelerate the improvement cycle?

MHE	Activity / Operation	Code	TMU	s	Frequency	Manip. Pal.	SUM	
FL	Gathering floor / storing 1,2m	**SAABFO**	981	35.32	1	4	8.83	**Pallet discharge**
FL	Driving	**SFISF**	13	0.47	5	4	0.5875	
FL	Lever forklift control - Gathering floor	**PT**	32	1.15	1	4	0.2875	
FL	Lever forklift control - Storing 1.2	**PT**	48	1.73	1	4	0.4325	
FL	Reading position storage placement / position number - 1x	**IALW**	25	0.9	1	1	0.9	**Transport from receiving area to shelves area**
FL	Gathering receipt area / Storing outside the shelf	**SAAAFM**	833	29.99	1	2	14.99	
FL	Gathering 1.2 / Storing 2,5 into the shelf	**SABCFM**	1243	44.75	1	2	22.37	
FL	Gathering floor/ Storing 2.5 m - shelf	**SAACFM**	1142	41.11	1	2	20.56	
FL	Driving process of shelving at storage place	**SFISF**	13	0.47	5	2	1.17	
FL	Lever control altogether - shelf	**PT**	216	7.78	1	2	3.89	
FL	Transport - direct - loaded	**SFISF**	13	0.47	130	2	30.42	
FL	Transport - curve - loaded	**SFKSF**	16	0.58	2	2	0.58	
FL	90° turn in driving direction unloaded	**SRFSF**	56	2.02	1	2	1.01	**Transportati on back**
FL	Transport - direct - unloaded back	**SFISF**	13	0.47	130	2	30.42	
FL	Transport - curve - unloaded back	**SFKSF**	16	0.58	2	2	0.58	
							137.03	**2.28 min.**
BAT	Battery charging (9,21/450)*forklift operating	0.04674377						
TECH	Control of technical conditions (4,95/450)*forklift operating	0.025122645						

Figure 2 – Analysis MTM for the Process

A work standard calculated by the MTM is usually an external input and it represents the optimum performance the operator shall be prepared to reach. The learning phase can last anywhere between a few weeks and a year, depending on several factors, such as a degree of automatization, task complexity, operators experience and qualification, etc. But usually one lesson is burnt deep in the operators' heads, when incentive earnings appear, steps are taken to find ways to tighten the time standards. On the other hand, when good conditions for organisational learning occur, they may help reach the standard faster, break mental models and later overcome the expected criteria by improvement actions from inside (Ezey, 2013).

3.2 3 J Program to Achieve the MTM Time and Reduce Variability

The traditional approach to job/work instruction (when engineering creates work standards and delivers job instructions to the manufacturing) shows several problems with implementation:

- Operators lack a deeper understanding of work instructions.
- Rarely can it be used as a problem-solving measure to eliminate waste from workplace/operation.
- Often it cannot fully reflect real situation on the line.
- It is slow, or not updated when change is made.
- There is only a weak motivation for internal improvement measures.

These problems are often the cause of a process instability and for that matter also process incapability. Basic stability of the process starts with the work standardisation and well-trained workforce. Stability is generated by doing the same thing the same way across operators and shifts. The importance of "training and instructing" instead of "telling" is the main concept of the TWI first "J program", Job Instruction. Job instruction is the program how to instruct a worker to perform a job correctly, safely and conscientiously (Huntzinger, 2006).

Processes are performed by various workers using different methods with different results, as in the Warehouse case. The Job Instruction requires identification of the best working standard for the process, training an employee to attain it, creating standardised work thereby. We use the MTM analysis result and work decomposition and create a work instruction (Fig. 3). The working standard was developed as the Job Breakdown through a description of:

- **Important Steps** (WHAT?) of the process - Pallet load, Transport of loaded pallet form receiving area to shelves, Transport back to the receiving area.
- **Key Points for each step** (HOW?) - might make or break the work, important to avoid injury, errors, make the work easier.

- Determination **of reasons for the key points** (WHY?).

Figure 4 shows the experience of time measurement of the transport process from receiving area into shelves after the first JI training following the 4 - steps training methodology: 1. Prepare the worker. 2. Present the operation according to Job breakdown. 3. Try worker outperformance. 4. Follow-up.

Proper working instruction eliminated variability and reduced average time from 2.85 to 2.64 min. Residual variability is caused by traffic situation in the warehouse. Forklift drivers often must stop and yield to other vehicles. After first "J", a variability reduction of 0.22 min was achieved.

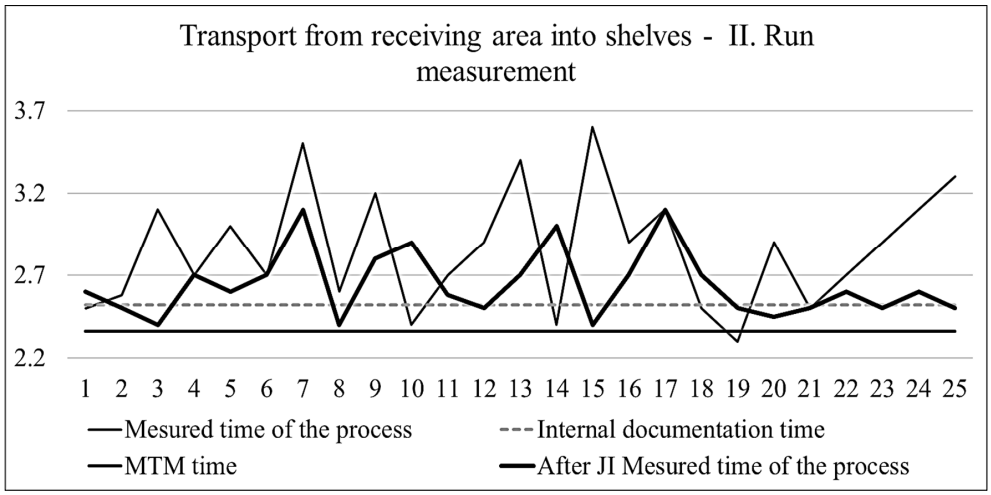
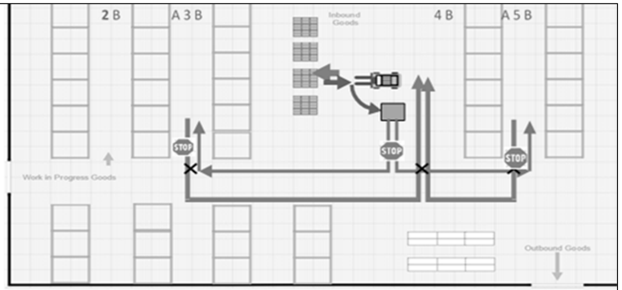


Figure 3 – Transport from Receiving Area into Shelves - Process Time (min) II. Run Measurement

Job Methods (JM) is the next TWI program (not applied in the study, but shall be developed to accelerate internal improvements). There is a real prospect of avoiding logistics MUDA in the warehouse with application of JM and of achieving the MTM standard time thanks continuous improvement.

Job Method evolved into KAIZEN – a Continuous Improvement concept, known as high volume of small incremental improvements from individuals. It is based on the Job Instruction experience conditioned by Standardised work. After proper training (training by doing) and deep experience with the process, JM helps individuals to break down the job to its details and to eliminate wasteful tasks, to combine and rearrange necessary tasks and to simplify those tasks that are required (Huntzinger, 2002).

Job Breakdown - WHSP 122	
Description of the task:	**Transport from receiving area into shelves**
Place:	Inbound warehouse /small parts. Receiving and shelves area section 2B,3A, 3B, 4B, 5A, 5B.
Parts, codes:	SMS V1 – V15
Tools & equipment **Staff** **Safety equipment**	Mobile Forklift/ 1.5–2.5 tonnes, Barcodes Scanner. Driver with FL license. Job Instruction passed WHSP122. Job Method - knowledge. Safety boots, leather gloves, helmet.
Time and quality	Total time: **137,02 s / 2,28 min.** Injury: **0 cases**. Damage of products: **0 €**. Damage of equipment: **0 €**. Incorrect operation - position error: **0**



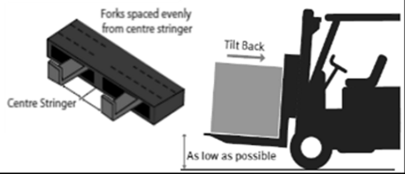
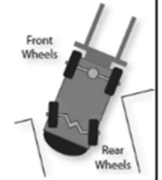
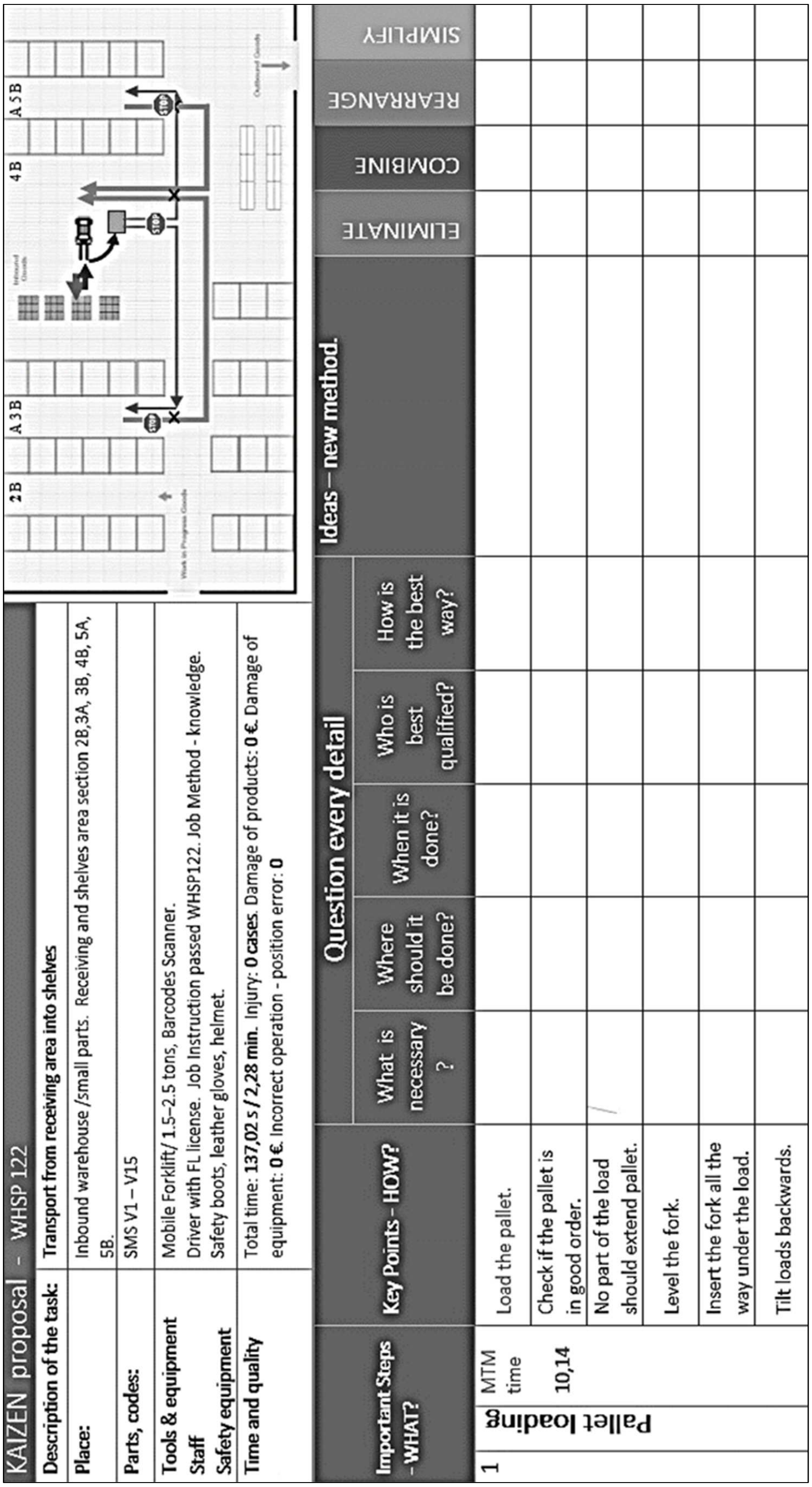
Important Steps - WHAT?		MTM time	Key Points - HOW?	Reasons - WHY?
1	**Pallet loading**	10,14	1.1 Load the pallet. Check if the pallet is in good order. No part of the load should extend pallet. Level the fork. Insert the fork all the way under the load. Tilt loads backwards. Lift up slightly. Low position. **1.2 Drive reverse 3 m and turn left.** Face the rear, sound horn before moving. 	1.1. Excess or unstable load may remain uncontrolled and cause a collision. To stabilise the forklift when it is loaded and during the transport. To validate centre of load gravity, or identify pallet problem. To make sure that the load is stable for transport and to keep visual road control. 1.2 To avoid an accident.
2	**Transport of loaded pallet from receiving area to shelve**	94,88	**2.1. Scan barcode - read storage location (** XX-X-X / Section – Lever – Position). **Stop and check the crossroads.** 2.2. **Transport the pallet to the shelving area.** Keep the transportation roads and road signs, speed limit 5km/h. Forks as low as possible from the floor. Load tilted back. Decrease speed at all corners, sound horn. **2.3. Turn in the direction of the storage position slowly.** Turn with the rear wheels. Do not turn a lift truck steering wheel sharply at fast speeds. Keep the safe distance from racks. **2.4. STOP. Brake. Lift pallet slightly to the location.** Not extend above the load backrest. Check that the overhead clearance is adequate and no persons aim to cross under the load. **2.5. Insert the pallet into the shelve –** smoothly, control position and dimensions. Store the palette in the location. Check stability. **2.6. Pull out the fork, reverse 1,5 m.** Face the rear, sound horn before moving  	2.1 To avoid incorrect operation and downtime. To avoid accident, injury and product damage. 2.2. To avoid collision with a pedestrian or vehicles. To avoid loaded forklifts to tip over or unexpected pallet movement. 2.3. To avoid loaded forklifts to tip over or unexpected pallet movement. 2.4. The part of the load extends beyond the backrest of the carriage can possibly slide back towards the driver. The falling pallet or object can injure crossing pedestrian or other vehicles rivers. 2.5. To avoid product damage and gain pallet safe position. 2.6. To avoid an accident.

Figure 4 – Job Breakdown – Job Instruction



KAIZEN proposal - WHSP 122

Description of the task:	Transport from receiving area into shelves
Place:	Inbound warehouse /small parts. Receiving and shelves area section 2B,3A, 3B, 4B, 5A, 5B.
Parts, codes:	SMS V1 – V15
Tools & equipment Staff Safety equipment	Mobile Forklift/ 1.5–2.5 tons, Barcodes Scanner. Driver with FL license. Job Instruction passed WHSP122. Job Method - knowledge. Safety boots, leather gloves, helmet.
Time and quality	Total time: **137,02 s / 2,28 min.** Injury: **0 cases**. Damage of products: **0 €**. Damage of equipment: **0 €**. Incorrect operation - position error: **0**

Important Steps - WHAT?		Key Points - HOW?	Question every detail: What is necessary?	Where should it be done?	When it is done?	Who is best qualified?	How is the best way?	Ideas – new method.	ELIMINATE	COMBINE	REARRANGE	SIMPLIFY
1 Pallet loading	MTM time 10,14	Load the pallet.										
		Check if the pallet is in good order.										
		No part of the load should extend pallet.										
		Level the fork.										
		Insert the fork all the way under the load.										
		Tilt loads backwards.										

Figure 5 – Job Method Example

JM involves 4 steps: 1. Job Breakdown (we used breakdown experience from JI). 2. Question all important aspects. 3. Develop the new method (eliminate the unnecessary, combine process parts, rearrange for better sequence, simplify and straighten process). By following the four-step Job Methods procedure, we can discover improvements based on workers' experience. An outline of the procedure was printed and given to the trainees (the template of the Job Methods form is shown in Fig. 5).

A similarity to KAIZEN can be seen in the phrases commonly used in eliminating waste and making work task improvements to perpetually drive improvement activities. The answers to "What?" identify unnecessary details to be eliminated. "Where? When? and Who?" give proposals for combining and rearranging. The answers to "How?" provide leads for the best way to simplifying. Job Methods is transformed to the well-known 5W 1H method.

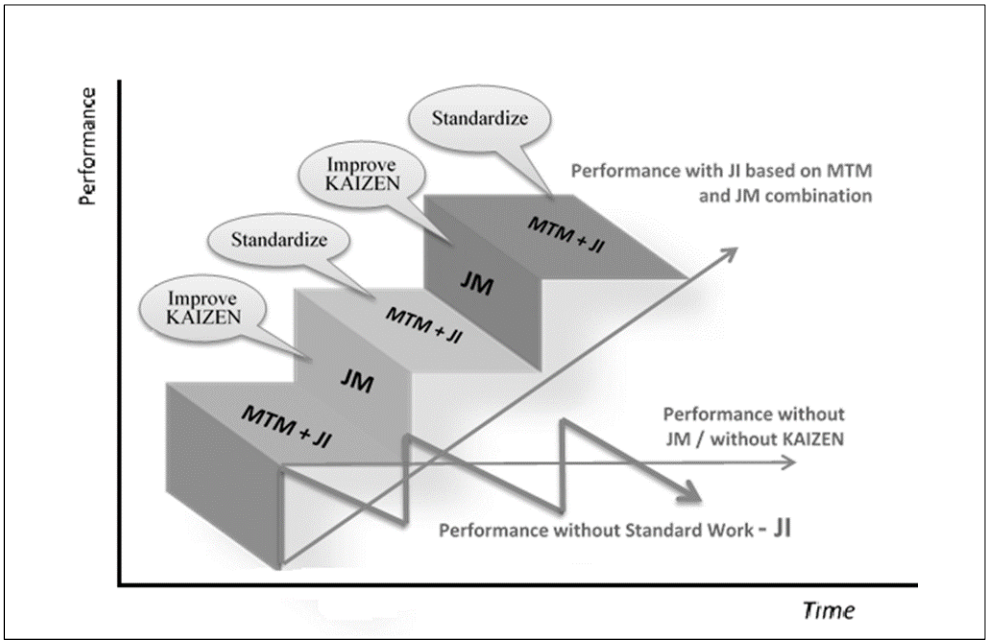


Figure 6 – JI and JM Combination Effect

Combining the JI based on the MTM job decomposition and the JM program a continuous improvement system can be developed. The MTM gives us internationally accepted basis for work standard and job instruction development. The JI helps to train the workers and provides them with a deep understanding of the work. After all JM opens the "Door" to accelerate Kaizen.

4 CONCLUSION

The MTM, as one of the predetermined motion time systems, is nowadays used in most countries in various industries. The basic goal is to achieve higher quality and work efficiency. Computer supported MTM opened opportunities to run MTM permanently, reflecting process changes, greatly reducing application time and the time to optimise processes. However, the MTM is characterised by several disadvantages. Predetermined motion times are generally determined from a broad sample of workers across several industries, they may not reflect the skill level, training, or abilities of workers in a specific company. There is less personal contact with employees. Therefore, the MTM standard as an external regulation often creates barriers to internal improvement. On the other hand, people have to live with the standards and achieve them. Continuous improvement system can be created in synergy with the TWI. This article introduces the concept of work standardisation based on the MTM method where the improvement is achieved through application of the JI and JM methods respectively. The Job Instruction method helps to avoid variability and achieve the standard time faster. The JM accelerates the improvement cycle to avoid inefficiency and waste.

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Socio-Economic and Regional Factors of Digital Literacy Related to Prosperity

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ABSTRACT

Purpose: to study social, economic, demographic, regional factors of digital literacy as a basis of digital prosperity.

Methodology/Approach: Three research questions are studied, using regression models for cross-sectional data - Pooling model, Random effects model and Fixed-effects model and the Item Cluster Analysis method.

Findings: Age, education, income and household type are the most significant factors of digital literacy, giving rise to the societal digital divide in Slovakia. Less important factors are the city size and the sector of the economy, but only weak is the influence of region, gender and nationality.

Research Limitation/implication: Only the contingency tables of the longitudinal surveys were available, so the microanalysis was not possible.

Category: Research paper

Keywords: digital literacy; digital prosperity; ICT revolution; vulnerable groups; regional disparities

1 INTRODUCTION ICT PRODUCTIVITY PARADOX

The progress of Information Technology (IT) into all areas of the economy and society has brought dramatic changes and defined the entry into the 21st century as a digital age. The development of information and communication technologies has caused utter structural changes entailing the issue of their impact on economic growth, the rise in labour productivity, cost reduction and improvement of living standards. There are many outlooks on the benefits of IT technology for humanity, and the achievements of the digital economy are accompanied by concerns about future prosperity, the ongoing divide of the world and society on the basis of the digital capabilities, and threats to prosperity due to the loss of typical jobs.

The growth economics hypothetically predicts that investment in ICT drives economic growth. However, several empirical studies on the impact of ICT have produced mixed results, being partly influenced by fairly differing research methodologies and focusing on different countries. In reality, the exploration of the ICT effects has recognised paradoxically stunning little effect on productivity in the first decades of the computer revolution. This is often denoted as productivity paradox (or Solow computer paradox) because the rapid expansion of the information technology in the United States has been accompanied by the deceleration in productivity growth in the 1970s and 80s (Solow, 1987; Baily, 1986; Dewan and Kraemer, 1998; Oliner and Sichel, 2000). The expenditures on ICT have risen in almost all of the world economies while productivity growth has slowed (David, 1990; Rei, 2004).

The paradox could be explained in various ways, e.g. as a result of imprecise traditional productivity measurement of the input-output relationship failing to take into consideration new sources of value. Another presumed important factor of the paradox is dealing with time lags in productivity rise associated with slow technology diffusion, learning requirements or insufficient use of technologies.

Recent statistical approaches have allowed more accurate new data to be compiled, and to quantify the hardly measurable IT impacts to date. Credible explanations could have been documented only over time showing a significant increase in productivity in companies that invested heavily in IT. Ultimately, however, the productivity increased in the period 1995-2000 from average 1.4 to 2.6 percent and it increased even more to about 3.6 percent even further in 2001-2003 (Brynjolfsson and Saunders, 2010). Today, there is already a consensus on the tangible productivity acceleration based on IT revolution as well as on the implication of the time lag caused by the very new demands of learning and using new IT technologies denoted as digital literacy.

2 DIGITAL LITERACY AND DIGITAL PROSPERITY

The ICT innovations and expected boost of productivity are impossible without the investments into worker ICT knowledge and skills. Digital organisations have

to afford more learning and training than in the other industries. It comes, employees need right IT skills and have to be trained to operate new digital processes, to search and find information effectively, but also to cope with exceptions and to make quick decisions. Digital literacy implies acting in new ways on information in digital form and through new organisational forms (Aral, Brynjolfsson and Van Alstyne, 2006; Brynjolfsson and Brown, 2005). New technology always plays a key role in discovering and determining new skills considered necessary for its enforcement in the economy. Growth driven by IT revolution is of course not possible without encouraging digital literacy and adoption of digital technologies. The deployment of ICT technologies in all the sectors is resulting in a new situation demanding for broad new skills.

Computers have long been regarded as a sole concern of hardware and programming specialists, requiring advanced new skills, what has evoked defensive reactions from the workers and hindered in their massive placement. Later, the Internet diffusion added significant pressure on the use of further Internet literacies. Digital literacy as a term has been first introduced rather generally, as an "ability to understand and to use information from a variety of digital sources", as required by new digital age (Gilster, 1997). Also, some other authors argue and consider digital literacy as a special kind of mindset or thinking and not only a practical ability to use digital sources effectively.

Over the past three decades, several approaches have emerged to classify old and new literacy skills that are needed in the 21st century in workplaces and have been gradually introduced into education. Already before, computer and information literacy terms have been in use (Bawden, 2001; Behrens, 1994). The computer literacy is related to traditional computers, emphasising practical skills in using computer and software application packages. In comparison, information literacy is focused on the ways, in which information is accessed and evaluated (Martin, 2006), accentuating the location and identification, further evaluation, and use of media.

Also, a skill set can be assigned to digital literacy and one of the esteemed skill designs is named 21st-century skills (Warschauer and Matuchniak, 2010). Today, after many confusing attempts and critical discussions, digital literacy can be considered as an integrating framework of several forms of literacy and skill-sets (Martin, 2006).

Developed countries have therefore introduced digital literacy into general education as the prevalent majority of their citizens become an active element of the digital economy. Lack of digital literacy is a key factor of the low prosperity. The positive aspects of the impact of IT on productivity and growth also cause adverse effects of increasing economic and social disparities and creating a digital divide (Hoffman, 2008). ICT and the Internet have considerable power to strengthen traditional forms of inequality on the basis of uneven access to computer devices and internet and level of digital literacy.

The previous reasoning enables to understand better the impact of ICT on productivity and to emphasise the role of digital literacy in achieving national or regional prosperity. Digital prosperity requires identification and understanding the factors behind the spatial distribution of digital prosperity and literacy, which have a capacity to even deepen poverty in less developed, rural or peripheral regions. At the same time, there are more vulnerable groups of the population due to worse Internet access and computer technologies, disadvantaged by age, gender, income or family situation. This gives a motivation to formulate research questions to explore the vulnerability of social groups and regions in their relationship to maturity in digital literacy and its development over time. In addition to evaluation of digital literacy factors and prosperity, it is possible to conclude which types of digital literacy are essential for developing digital literacy as a whole. These results have clear implications for school education, the training of employees and working with disadvantaged social groups.

3 RESEARCH QUESTIONS AND METHODOLOGY

Research and analysis are based on the representative surveys carried out by the Institute for Public Affairs (Inštitút pre verejné otázky, IVO), Bratislava. Data were collected within the long-term project the Digital Slovakia during the period 2005-2015 and provide an all-embracing picture of the digital skills of the citizens of Slovakia in time and space, following several economic, social and demographic parameters. The publicly available dataset has a form of contingency tables displaying statistical panel data in three dimensions: categories of digital skills and related social phenomena, demographic characteristics and years of observations. The surveys were realised on the representative samples among the population of Slovakia on the sample of 1,000+ inhabitants older than 14 years biannually (2005-2015). The quota sampling took into account the parameters of gender, age, education, nationality, settlement size and region. The results are published in a form of tables and charts, comparing a set of digital literacy indicators, and values of the composite Digital Literacy Index (Velšic, 2011) according to above quota parameters.

In this article, digital literacy skills are classified into two categories of General Skills (GS) and Internet and communication skills (ICS). The GS category consists of three general components: Access to digital tools in broad sense (Ac), Hardware skills (Hs) and Software skills (Ss). The ICS category is divided into two components of Internet skills (Is) and Communication skills (Cs).

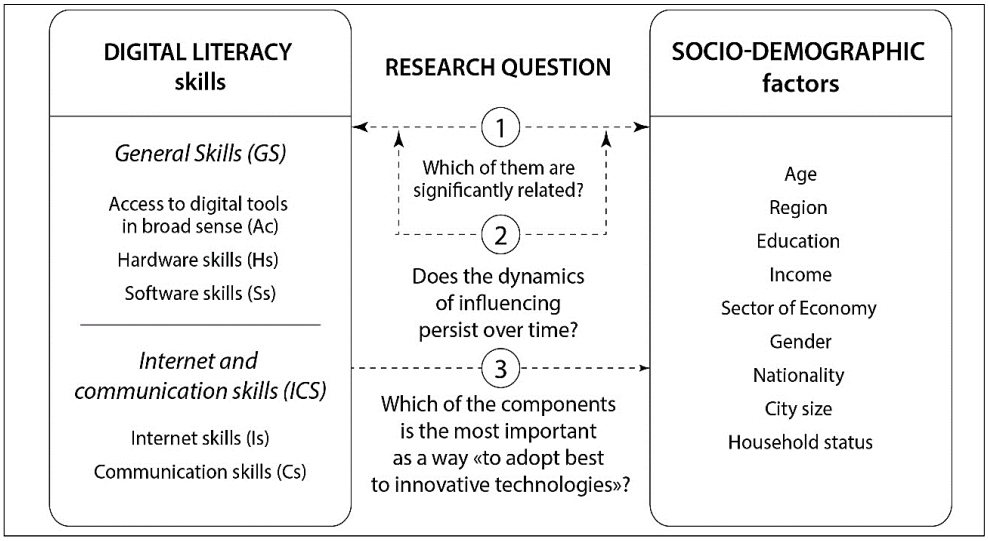

Figure 1 – Research Framework

In general, lower digital skills could be expected due to elderly age, lower education, smaller city size or lower income families. Hence, the first research question is formulated as follows:

Research Question 1: Which of the socio-demographic factors are significantly related to value of the aggregated components of digital literacy?

Altogether 10 socio-demographic indicators are subject to correlation analysis with 5 groups of aggregated items of digital skills. The list of variables, categories and coding is shown in the following Tab. 1.

Table 1 – Factors, Categories, and Coding of the Digital Literacy Surveys

Factor	Code	Category
Age	1	14-17
	2	18-24
	3	25-34
	4	35-44
	5	45-54
	6	55-59
	7	60-
Region	1	Bratislavský
	2	Trnavský
	3	Trenčiansky

Factor	Code	Category
Sector of Economy	1	State-owned
	2	Public
	3	Cooperative
	4	Private
Gender	1	Male
	2	Female
Nationality	1	Slovak
	2	Hungarian
	3	Other
City size	1	Less than 2 thousand

Factor	Code	Category
	4	Nitriansky
	5	Žilinský
	6	Banskobystrický
	7	Prešovský
	8	Košický
Education	1	Elementary
	2	Vocational
	3	Secondary
	4	Higher
Income	1	Very well-off
	2	Relatively well-off
	3	Average level well-off
	4	Inadequately well-off
	5	Poor

Factor	Code	Category
	2	2 - 5 thousand
	3	5 - 20 thousand
	4	20 - 50 thousand
	5	50 - 100 thousand
	6	Above 100 thousand
Household status	1	Young persons
	2	Young children household
	3	Average age children household
	4	Adult children household
	5	Three-generation household
	6	Elderly household (no children)
	7	Senior citizens
	8	Other household

Of course, it is notable to study how digital skills change over the period of 10 years and what the nature and pattern of the digital skills dynamics are. It might be expected that some factors of digital divide will lose their influence over time. Hence, a special class of regression models for cross-sectional data can be applied to study time effect including fixed effects, random effects and independently pooled time series effects as the second research question:

Research question 2. Does the influence of socio-demographic factors on digital skills level persist over time?

Given the proposed structure of skills, the third research question is dealing with possible improvements in the individual digital literacy and the ways how to set up the education and training effectively. The hierarchical clustering algorithm is used to study the structural relationship between the five components of digital literacy:

Research question 3. Which of the components of digital literacy under study are the most important to focus on to improve universal individual digital literacy as a way to adopt best to innovative technologies?

The original dataset had to be significantly modified, scaled, normalised and aggregated into categories subject to three models.

The final dataset consisted of three dimensions represented by the variables and corresponding data:

1. Digital skills, aggregated into 5 components: Access to digital tools in broad sense (Ac), Hardware skills (Hs), Software skills (Ss), Internet skills (Is) and Communication skills (Cs).
2. Socio-demographic factors, aggregated into 9 categories of factors (Gender, Age, Education, Income, Nationality, Household status, Sector, Region, City size).
3. G1 as the dependent output variable is based on the answers in the surveys 2005, 2011, 2013, 2015: "How do you adapt and learn to master modern information and communication technologies (computers, the internet, electronic mail, electronic banking, etc.)?" It is supposed, the level of adaptation depends on the individual current computer skills, and directly describes the subjective ability to improve individual digital literacy.

4 DATA SOURCE DESCRIPTION AND BASIC STATISTICS

In accordance with the concept and the framework outlined above, digital skills indicators were selected and grouped into 5 components:

Table 2 – Groups, Components and Variables of Digital Literacy

Group	Component	Var	Skills
GS: General skills	Ac: Access to digital tools (in wide sense)	Hw1	Working with PC (desktop)
		Hw2	Working with a laptop/smartphone
	Hw: Hardware skills	Hw3	Printing documents on a PC printer
		Hw4	Work with the scanner
		Hw5	Write data to portable media
		Hw6	Install hardware to PC
		Hw7	Carrying / Copying Data on LAN
	Sw: Software skills	Sw1	Working with a word processor
		Sw2	Work with a spreadsheet
		Sw3	Working with a database program
		Sw4	Working with a graphic editor
		Sw5	Working with a multimedia program
		Sw6	Working with an Internet browser
		Sw7	Install software and set up PC features

Group	Component	Var	Skills
ICS: Internet and communication skills	IS: Internet skills	IS1	Search for information and services on the Internet
		IS2	Registration of access to information and services on the Internet
		IS3	Using Internet Banking
		IS4	Purchasing goods or services over the Internet
		IS5	Search for different information in LAN
		IS6	Download/upload files, data over the Internet
	CS: Communication skills	CT1	Send and receive emails
		CT2	Chat / video chat communication
		CT3	Sending messages from mobile phone/smartphone (SMS, MMS)
		CT4	Internet telephony (VoIP)
		CT5	Communicating in newsgroups, forums, fanclubs

The general components of digital literacy describe basic skills, including elementary ability to work on a computer, stationary or portable (AC), work with various kinds of software (Sw), and particular skills that enable solving simple hardware issues (Hw). The most important for the concept of digital literacy as a tool for achieving digital prosperity are the skills assigned to the ICS group. Namely, two components of the ICS group (Internet and communication skills) are vital for direct provision of goods and services and communicating with people and institutions.

To check the consistency of the grouped skills obtained from the surveys, Alfa Cronbach values were calculated showing high internal consistency in all variables (alpha values always greater than 0.90). The relation between aggregated ICS group skills and 9 socio-demographic factors are visualised in the following pictures (Fig.2).

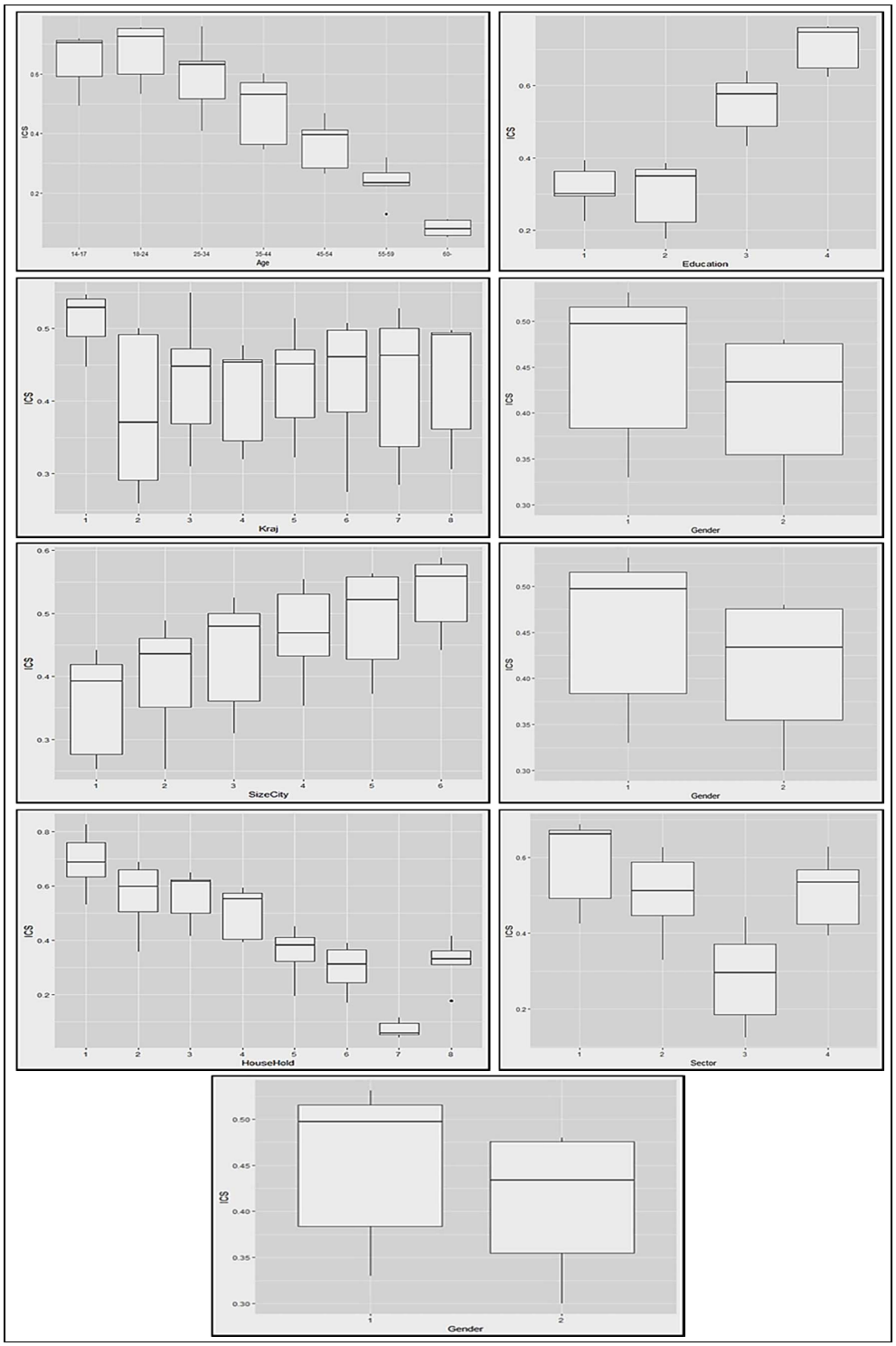

Figure 2 – Boxplots of the Relationships between the ICS Aggregated Skills and Socio-Demographic Factors

The visual difference between the average values of individual socio-demographic factors is suggesting confirmation of the influence of the relevant factors on internet and communication skills such as age, education, income or city size. Digital divide and its borderlines can be seen immediately as a positive or negative correlation. Because of different type of variables (binary, nominal, ordinal), different measures of correlation or association testing have to be applied. A more detailed exploration of dependencies and dynamics following the research questions is presented in the following section.

5 STATISTICAL ANALYSIS AND RESULTS

Correlations between the socio-demographic variables (ordinal, nominal or binary scale) and the five components of digital literacy (interval scale) (Research question 1) require the use of different methods.

The Spearman coefficient is obviously appropriate for measuring correlations between the ordinal and interval scales.To calculate the correlation between the nominal and the interval scale, the Etha coefficient is recommended (Levine and Hullet, 2002). The association between the dichotomous and interval variables (Gender) can be tested by the rank-biserial correlation coefficient (Kerby, 2014). All the results on correlation or association are presented in Tab. 3.

Table 3 – Association between the Socio-Demographic Variables and Components of Digital Literacy

Factor	Scale	Coefficient	Ac	Hw	Sw	Is	Cs	Association
Age	ordinal	Spearman	-0.86	-0.91	-0.94	-0.85	-0.9	strong negative
Region	nominal	etha squared	0.08	0.25	0.28	0.15	0.14	weak positive
Education	ordinal	Spearman	0.86	0.83	0.82	0.87	0.85	strong positive
Income	ordinal	Spearman	-0.91	-0.94	-0.95	-0.91	-0.92	strong negative
Household	nominal	etha squared	0.81	0.88	0.9	0.79	0.81	strong positive
City size	ordinal	Spearman	0.48	0.71	0.75	0.56	0.61	Positive
Sector of Economy	nominal	etha squared	0.53	0.71	0.75	0.49	0.53	Positive
Gender	binary	biserial	-0.3	-0.47	-0.45	-0.36	-0.25	weak negative
Nationality	nominal	etha squared	0.29	0.49	0.51	0.31	0.29	weak positive

The values of the coefficients estimate the strength of the association between socio-demographic factors and the components of digital literacy. The four of 9 socio-demographic factors considered have a significant effect on digital skills levels – age, education, income and household type. The city size and the sector of the economy also show an influence on digital skills. However, only a weak

influence relates to factors of region, gender and nationality, which are therefore detached from the further consideration.

In the second research question, the dynamics of the socio-demographic factors influence is tested. Three most-known regression models are selected for the analysis: Pooling model, Random effects model and Fixed-effects model. All three models can be written in the form:

$$y_{it}=\alpha+x'_{it}\beta+z'_i\gamma+c_i+u_{it} \quad (1)$$

whereby

i refers to a cross-sectional unit such a household;

t refers to a unit of time such as a year from 2005 till 2013;

x'_{it} is a time-varying explanatory variable such a category of digital skills;

z'_i is a time-invariant explanatory variable such a socio-demographic factor;

β and γ are coefficients related to type explanatory variables above;

c_i is within cross-sectional unit error, that is time-invariant but varies across cross-sections;

u_{it} is between cross-sectional unit error, that varies over time and households (our cross-sectional units), and is a truly stochastic error term.

Pooling model (P) assumes that the groups or objects under consideration do not have individual differences, that is, the data can be viewed as a general time series, without a panel structure, so it is assumed $c_i = 0$. In the fixed-effect model (FE), each unit is considered "unique" and cannot be regarded as a result of a random choice from a certain general population, so it is assumed c_i depends on x_i. This approach is often confirmed when the cross-sectional units under study have important time-invariant differences that persist over time. If the objects are in the panel "accidentally" as a result of sampling from a large population (so c_i and u_{it} depend on x_i), then the model with a random effect (RE) is acceptable.

Standard hypothesis testing techniques make possible to choose a model taking into consideration hierarchy among them. The pooling model P is a special case of both models FE and RE. Also, the model with random effects RE can be regarded as a special case of the model with fixed effects FE.

When testing the statistical hypotheses for the choice of the model, the null hypothesis is stated as validity of a narrower model, and the alternative hypothesis relates to a more general model. Thus, the model and its coefficients are tested to determine their significance. The Tab. 4 displays the coefficients of the three models for significant social-demographic factors: age, education, income, household type, employment sector and city size.

Table 4 – Regression Coefficients for Social-Demographic Factors

Factor	Model	Coefficients				Estimation of model	
		Intercept	AC	Hw	Sw	p-value	R2
Age	pooling	0.004	0.461	0.420	0.139	< 2.22e-16	0.991
		0.648	0.00022 ***	0.113	0.486		
	random effects	0.004	0.457	0.435	0.128	< 2.22e-16	0.992
		0.617	0.00024 ***	0.098	0.522		
	fixed effects		0.343	0.159	0.771	< 2.22e-16	0.963
			0.019*	0.573	0.0065 **		
Education	pooling	-0.007	0.879	-0.632	0.779	4.93E-14	0.981
		0.795	0.00114 **	0.364	0.201		
	random effects	-0.007	0.879	-0.632	0.779	4.93E-14	0.981
		0.795	0.00114 **	0.364	0.201		
	fixed effects		0.592	-0.163	0.793	2.98E-06	0.880
			0.240	0.876	0.233		
Income	pooling	0.024	0.535	-0.019	0.475	< 2.22e-16	0.983
		0.104	0.005625 **	0.968	0.258		
	random effects	0.028	0.562	0.213	0.185	< 2.22e-16	1.000
		1.84e-06 ***	2.647e-05 ***	0.180	0.344		
	fixed effects		0.382	0.306	0.526	4.81E-08	0.880
			0.09491	0.607	0.263		
Household	pooling	-0.013	0.796	-0.704	0.973	< 2.22e-16	0.985
		0.247	1.34e-07 ***	0.073	0.0067 **		
	random effects	-0.011	0.783	-0.655	0.934	< 2.22e-16	0.987
		0.283	1.52e-07 ***	0.09019	0.0084 **		
	fixed effects		0.853	-1.328	1.764	< 2.22e-16	0.948
			1.393e-06 ***	0.00479**	0.00011 ***		
Sector	pooling	-0.044	0.980	-0.702	0.812	8.10E-13	0.973
		0.08993	9.652e-05 ***	0.08902	0.022 *		
	random effects	-0.044	0.980	-0.702	0.812	8.10E-13	0.973
		0.08993	9.65e-05 ***	0.0890	0.022 *		
	fixed effects		0.748	-0.683	1.246	2.95E-09	0.959
			0.016460 *	0.154	0.0041 **		
City size	pooled	-0.082	0.434	-0.070	0.949	< 2.22e-16	0.947
		0.00738 **	0.0019 **	0.831	0.0073 **		
	random effects	-0.056	0.386	0.146	0.710	< 2.22e-16	0.970

Factor	Model	Coefficients				Estimation of model	
		Intercept	AC	Hw	Sw	p-value	R2
		0.015539 *	0.001787 **	0.625	0.0274 *		
	fixed effects		0.302	-0.017	1.216	3.32E-12	0.929
			0.131	0.966	0.0041 **		

Comparison of the models exploits three different tests:

1. The standard F-test: fixed effects model against pooling regression. Null hypothesis: the pooling model is correct/fixed effects model is incorrect.
2. The Hausman test: fixed effects model against random effects model. Null hypothesis assumes consistency of the coefficients in both models. If rejected, the coefficients are untenable in the RE model.
3. The Breusch-Pagan test: random effects model against pooling regression. Null hypothesis assumes the pooling regression is correct.

Table 5 – Testing of the Dynamics of the Socio-Demographic Factors over Time

Test	F-test	H-test	BP-test	Conclusion
H0:	Pooling	RE	Pooling	
H1:	FE	FE	RE	
Age	0.059	0.001	0.663	fixed effect model is significant
	H0	H1	H0	
Education	0.867	0.924	0.155	random effect model is significant
	H0	H0	H0	
Income	0.6615	0.2931	0.09201	random effect model is significant
	H0	H0	H0	
Household	0.0811	0.002716	0.6645	fixed effect model is significant
	H0	H1	H0	
Sector	0.2183	0.05028	0.6674	random effect model is significant
	H0	H0	H0	
SizeCity	0.6262	0.02398	0.2791	fixed effect model is significant
	H0	H1	H0	

The model with fixed effects well represents three factors of Age, Household type and City size showing individual group differences. In other words, the differences of the digital skills in groups divided by Age, City Size, and

Household Type are significant and time invariant. By contrast, Education, Sector of economy and Income are well described by the random effects model indicating the differences in the groups are not confirmed. Progressing Internet accessibility and affordability have brought lower dependence of Digital skills on higher education, income or special skills related to the sector of employment.

At last, the Research Question 3 is studied, namely which of the components of digital literacy is the most important for increasing individual digital literacy as a way to adapt to innovative technologies. In other words, to figure out, which digital skills have a potential to serve as means to overcome the societal digital divide and to increase individual digital literacy. To understand the role of the single digital skills in improving digital literacy, the indicator of adaptation to digital tools (denoted below as Adapt) is employed.

The structural model is proposed to test associations between the components of digital literacy using the Item Cluster Analysis method (ICLUST). The items used in correlations are variables, and similarly to factor analysis, the aim is to reduce the data complexity and to identify homogeneous clusters – subgroupings (Revelle, 1979). Hence, the result of the ICLUST method is the tree diagram showing the nesting structure of the clusters of items - variables. Also, this method is employed to analyse the adequacy of scales in use and to decide whether the assumed constructs are measured properly. Indeed, the indicators are consistent with the components, as pointed by the high Cronbach alpha value 0.95 and the average value of the factor saturation (Betta Revelle) equal to 0.58.

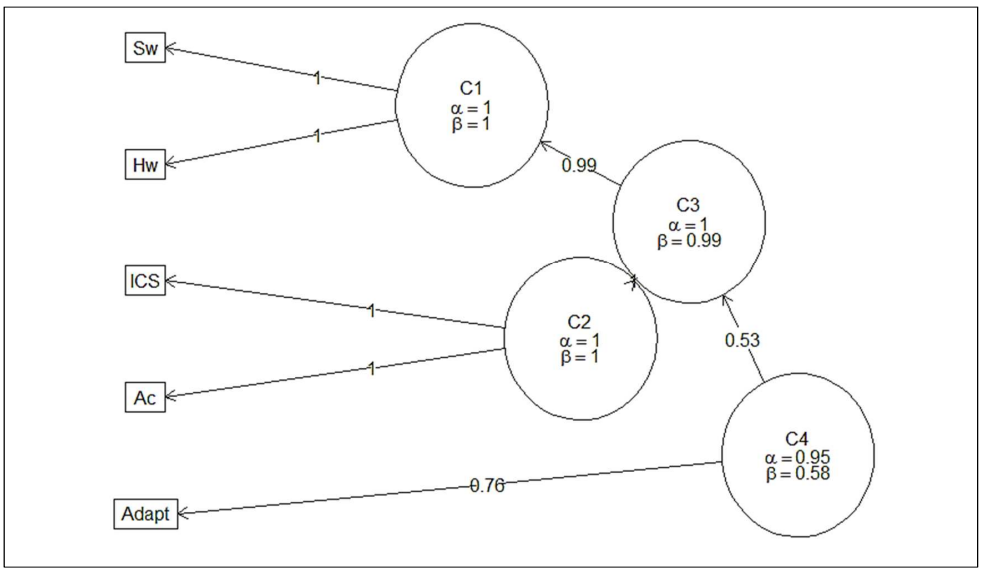

Figure 2 – Hierarchical Clustering of the Digital Literacy Components

The linear model, residuals and coefficients are as follows:

ModelAdapt ← lm(Adapt ~ Ac + Sw + Hw + ICS, data = DL)

Residuals:

Min	1Q	Median	3Q	Max
-0.030500	-0.010688	-0.003643	0.009144	0.030970

Coefficients: Estimate Std. Error t value Pr(>|t|):

(Intercept)	0.025610	0.008981	2.852	0.01154 *
Ac	0.489713	0.138074	3.547	0.00268 **
Sw	-0.311235	0.221357	-1.406	0.17884
Hw	0.358001	0.338263	1.058	0.30561
ICS	0.555943	0.229376	2.424	0.02758 *

Residual standard error: 0.01749 on 16 degrees of freedom.

Multiple R-squared: 0.7613, Adjusted R-squared: 0.7016.

F-statistic: 12.76 on 4 and 16 DF, p-value: 7.48e-05.

The regression table shows significance of the built model with a p-value 0.017 < 0.05 and fairly high R-squared is 0.76. So, the assumption about dependency between the Adaptation to new digital tools and existing digital skills is confirmed. Besides, the significant variables are AC (basic ability to work with PC) and ICS (Internet and Communication skills). The software skills and Hardware skills are not essential.

6 CONCLUSIONS

The digital prosperity of society is believed to be achieved through learning and improvements of the individual digital literacy. The research has determined socio-demographics factors having the greatest impact on a variety of digital skills and which of them retain their effect over time. The existing digital divide has a negative impact on the social groups with specific socio-demographic profiles such as elderly people, households without young people and inhabitants of smaller settlements. Widely assumed factors of lower education, low income and regional affiliation confirm additional negative impact, but their influence is decreasing due to the better availability and affordability of digital services and internet. A study of time-series dependencies has shown that despite the overall digital literacy is increasing, the digital divide remains similar in the course of time.

The study has identified the most relevant digital skills for general digital literacy as working with a computer, the Internet and digital communication skills. Two other groups skill categories – working with hardware and software represent less necessary skills for a general digital literacy, having only additional positive

influence and representing skills which remain indispensable to selected groups of IT professionals.

The digital economy and society development requires higher digital literacy, and several social-demographics factors represent typical factors of exclusion. To ensure democratic principles towards to digital prosperity, it is supposed to provide equal opportunities to all demographic groups. This is the role of the government and regional stakeholders, to shape the education, learning and trainings having capacity in reducing the divide. The study gives several hints on sensitive socio-demographic factors of digital divide, as well as about the key areas of intervention.

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