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A Real-Time Model for Mobile Knowledge Management

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Abstract. There has been a rapid evolution in virtually all areas of information-based technologies over the past several decades. Among them are knowledge management (KM) and KM systems (KMS). KM is underpinned by a KMS that imparts the functionality and services to support organizational operations. KM is thus described as a process made up of 3 main actions: 1) Knowledge production; 2) Knowledge acquisition; 3) Knowledge transfer. In addition to this there have been advances in information delivery modalities that in combination with KM have greatly enhanced the availability and utility of information today on a global scale. The wireless industry in particular has now emerged as the dominant mode of personal and business communications. Siemens predicted a new-age mobile-wireless enterprise would emerge as a logical extension of the mobile workplace capable of meeting the real-time requirements and challenges of continuous, instantaneous communications (Siemens.com, 2006). Furthermore emerging virtual technology platform proponents have recently begun advocating and advancing the virtualization of information infrastructure such as Cloud Computing with a focus on disaggregation of services anywhere, anytime, for anyone (Datacore.com, 2008).

KM and KMS, along with a new global Internet and wireless landscape, extends personal collaboration and communications domains well beyond the traditional and historical limits of both information processing and data management capabilities. However there is a lingering dilemma associated with the preponderance of available literature and models for knowledge transfer that approaches it as primarily process oriented and event driven. Moreover all of currently available models fail to provide a means by which to quantify and measure the amount of knowledge transferred thereby limiting the ability to fully harness the power thereof.

This paper thus presents an operational model implemented to measure knowledge transfer in a more "real-time" setting with a focus on field maintenance and repairs associated with the radio access network element known as the base station transceiver or BTS which is linked to a mobile switching center (MSC). The MSC operating environment provides an inherent abundance of data and parameter-rich operating conditions and associated radio system measurements that afforded a propitious opportunity and ability to test the model. The main objective was to prove that knowledge transfer, in addition to being an organizational process is also a quantifiable and measureable activity in constant motion among and between all of us every day.

A cross-sectional review and analysis of operational data and information obtained from surveys from eight unique and geographically dispersed MSCs were used to test the efficacy and value of the KT model for "real-time mobile knowledge management". The output of the statistical analyses revealed possibilities for improving operating effectiveness and efficiencies of both wireless and non-wireless industries. More research however is strongly recommended to further validate any potential value and overall efficacy of the model.

Keywords: Mobile, Knowledge Management, Knowledge Systems, Knowledge Transfer Measurement, Mobile Switching Centre, wireless industry, Base Station Transceiver, Next Generation Network, Personal Communications Network, Intelligent Network, Mean Time to Repair.

1. Introduction

Wireless (or Cellular) networks have rapidly evolved over the past 3 decades delivering 4 generations of

Technology and mobile services to an estimated 2.7 billion users worldwide of which over a billion of them today are now considered valuable knowledge workers (IDC.com, 2006). The wire*l*ess industry today owes much of its evolution to the lesser known Intelligent Network (IN) infrastructure that itself evolved through the 1980's and 1990's. The simultaneous evolution of IN and wireless as such gave rise to a new type of networking known as the Personal Communications Network or PCN. The PCN in turn gave rise to the concept of the "next generation network" or NGN embodying the idea of "seamless" or transparent network connectivity. The NGN moreover supports video, voice, and data transmission simultaneously now referred to as multimedia services ensuring end-user connectivity anywhere, anytime on any provider's network hence the term seamless. NGN wireless technology is now the most widely used communications.

Hence, a new age of mobile communication and computing has now emerged spawning a new type of business known as "m-business" (Umar, 2004) predicted to soon become, if not already, the primary medium for business-related information exchange for and among next generation enterprises or NGE's. The m-business model is expressed as a sum of e-business, wireless networks, and mobile devices which underscores the proposal in this paper, that future use of KM and KMS will be greatly enhanced by their synergy. Similarly, use of wireless devices and technologies in the future may rely much more on KMS implementations to more efficiently and completely access, retrieve and leverage their total organizational knowledge infrastructure and resources.

The purpose of this research was to determine if a wireless-enabled KMS and networking infrastructure can enable and improve knowledge transfer during BTS repair in a way that an improvement in the Mean-Time-To-Repair (MTTR) can be realized. As such it was necessary to capture, quantify and validate several pertinent measurements in a suitable operating environment and ultimately be able to determine from those the impact on the enterprise operation. The study subjects thus chosen were wireless (MSC) operators from selected U.S. wireless companies who are generally responsible for various remote base station maintenance and repairs in varying degrees.

In addition a comparative analysis was performed to determine the type and use of both portable-wireless technology and IP networking by MSC staff to enable and facilitate knowledge transfer in the course of performing base station or BTS maintenance and repairs. Furthermore, the focus of this study was intentionally limited to the effects of wireless- enabled and non-wireless enabled KT on live operations rather than on a narrow pedagogical treatment of KT as a mere subset of KM. The main objective of the study was to demonstrate how the superior quality of a wireless delivery modality works in combination with an installed KMS capability to both minimize and optimize the BTS MTTR during system outages. To do so required a common value to express MTTR, KT and other related variables to determine whether minimization or optimization did in fact occur. Hence, a universal unit of measurement in the wireless industry for voice calls referred to as minutes of use (MOUs) was chosen and adapted to this study and typically expressed as whole integer values from 1 to infinity (Freeman, R. 1999).

This research study involved collection of 3 main types of information and data from eight different wireless operators in 4 geographical areas of the U.S. Hence the following information was acquired, processed, and measured over a 5 busy-day operational cycle or work week.

1.) Operations repair-maintenance logs and outage reports (most dated but generally representative)

2.) Call detail records (CDR's) containing customer usage data (sparsely available)

3.) MSC staff utilization data related to base station repairs (often provided verbally by managers)

The following was the general analytical approach utilized in the research study.

1. Survey results and data provided by MSC staff and where necessary by substitution methods, records, etc. was input to the various charts and tables developed

2. All data obtained was transposed to the KT calculator in Table 2

3. Standard linear regression analysis & ANOVA to test model validity was performed

The theoretical framework for this study is based upon two main sets of criteria from Dixon,

2000 and Firestone, 2001 as it relates to knowledge transfer processes and models. In the former case (Dixon, 2000) the following are 5 "modes" of knowledge transfer defined;

1-Serial 2-Near 3-Far 4-Strategic 5-Expert

In the latter case (Firestone, 2001) all 5 of the Dixon modes would continually interact in varying degrees at all organizational levels. Hence in an operational sense then this would occur during BTS repair for MSC operators. In both cases the activities involve simultaneous exchange of both explicit and tacit knowledge among individuals, groups, and organizational levels on a local and wide area basis. The response framework and methods for the MSC operators are implemented to restore network outages and conform to Firestone's EKMS model traversing organizational levels and functions, to direct and channel knowledge into the needed organizational areas, groups, and individuals in the various portions thereof.

In recent years, businesses have increased their efforts to provider emote access to various internal resources in the firm to improve overall workflow and ultimately productivity (Siemens, 2006). Access to corporate networks in particular has started to receive greater attention addressing the type and quantity of services to provide, to whom, and the means to deliver them. The following general observations support this conclusion.

1. The majority of organizations today provide at least some remote access to databases and applications by workers.
2. A wireless-enabled KT capability within a firm improves employee access to and use of remote applications.
3. Network management extended applications are rapidly rising to the top of the most common types used by wireless communications product and service providers.

2. Methodology

As stated earlier this study was aimed primarily at determining what the overall impact is on the operational efficiency of a MSC as a function of mean-time-to-repair (MTTR) of cellular base stations when a wireless-enabled knowledge transfer mechanism is utilized by MSC field personnel. In terms of the application of measurement criteria for the study Pearson (1999) posited that a fully integrated system of measurement for an enterprise is a key factor in supporting such operations. Thus applying this logic in combination with a few generalized mathematical relationships toward development of a KT model for an MSC operation served to both demonstrate and validate the need to include the following 3 main measurement parameters.

1) Amount of time MSC staff are engaged in mobile-enabled KT measured in the units "minutes of use" (MOUs) associated with their work.

2) Average time required by MSC technicians to perform BTS repairs in relation to the total outage time expressed as "Mean Time To Repair" (MTTR) and,

3) Labor-hour impact accrued over the selected maintenance period or cycle as a function of the total available MSC field personnel.

The rationale for measurement #3is necessary to account for the differences between Tier 1, 2, and 3 operators such that different staffing levels would not bias results of statistics. Thus an MSC "factor" was computed and used as a coefficient of correlation for the kt, kr variables. All 3 of the conditions nevertheless bear a relationship to one another that when combined with the data can and were reliably employed in testing the KT model. The process begins by assuming that the activity of KT has more than just a qualitative dimension but a potential quantifiable component moreover based upon the view by most researchers that it is an activity involving a source, receiver, and channel (medium) for transfer. It is possible therefore to mathematically express a relationship for KTin terms of the following 3 states and their corresponding formulae.

1) Knowledge transmitted; 2) Knowledge received; and 3.) Knowledge output (Kt) expressed as ***KT = Kt + Kr*** where Knowledge Transfer(KT) = *knowledge transmitted* (Kt) + *knowledge received* (Kr) where Kt and Kr are both measured in *minutes of use* (MOU's).

This study demonstrates that it is possible to quantify and thus measure knowledge transfer and moreover the total operational impact of it on a modern enterprise as a function of both Kt and Kr and specification of the corresponding individual characteristics and actions thereof. There is also another level of functionality, a growth function “f“ that is assigned to Kt and Kr to define their independent mathematical and dimensional relationships based on the assumption of the existence of both a time and space component forming part of the "fully integrated measurement system for the total enterprise" (Pearson, 1999). Other reasoning for this assumption is supported by Leslie (2007) with regard to economic firm-based theory which defines the production function Q = f (L,K) in terms of its associated variables; L-Labor and K-Capital and a function "f" as a linear product of values. Additional studies by Pakes and Griliches (1984) provided a general formula for a knowledge production function Y=f(X,t), where Y=knowledge output and is based on a technology variable called “X” and its conjugate t to describe a corresponding change in X. We further defined an output value Qt for KT modified by a “growth” function f derived from the percentage distribution of digital device utilization during BTS repair obtained from the survey data. This results in the final expression Qt=f (Kt,Kr) to express instantaneous knowledge output as a function of wireless and non-wireless activities. Qt therefore represents the total knowledge transfer attainable through the combined actions of knowledge transmitted and received expressed as input values Kt and Kr occurring at varying levels and durations in the transfer process. These actions moreover result in a unique but predictive output that were eventually tested and validated in both graphical and statistical analyses later in the study. In order to facilitate the analysis however, it was also necessary to assign a fixed value to f in the expression for Qt in an effort to define how much time on average is spent sending and receiving. Hence, a value of 33% was eventually arrived at and assigned which translates to a 60/40 ratio and thus relationship of Kr to Kt. The underlying assumption is that approximately 33% more time is spent receiving than sending data based more on observations over time as well as sparse test results. Thus while other ratios were tested the 60/40 ratio was found to have a more optimal relationship in the pre-tested outcomes when applied to a final expression for total knowledge transfer KT= (Kt+Kr).

An equally important component of this methodology is the underlying technology and resulting efficiency as a function of system utilization levels expressed as the “mean time to repair” or MTTR unit of measure described earlier. MTTR in this study as such relates input to output device-utilization levels as a function of KT and therefore the main identifier of and expression for BTS repair rates. An additional variable Qk was then introduced as part of the formula for MSC to account for differences in staffing levels stated earlier as well as to the availability of resources applied to BTS repair and maintenance. Hence, Qk now forms a linear relationship with respect to MTTR and KT to conform to the Pearson correlation construct.

As mentioned earlier the primary instrument for this study was a survey questionnaire sent out to pre-selected wireless operators and then followed up by formal and informal interviews by both email and telephone. In most cases the operational data was provided by switch and operations managers that while consistent in many respects was also often incomplete requiring use of estimation or extrapolation methods to replace data. In cases where too much data was missing data substitution methods and associated software was employed to fill in any of the missing data eg. data imputation. The scope of the questioning nevertheless was still designed to meet the minimum requirements for the needed amount of survey data, instrument reliability, and computational accuracy. The specific instrument constructs for the study are average hours and days spent each week in BTS repairs, the number of MSC personnel and the time spent by MSC staff conducting wireless and non-wireless communication. Calculations were then performed on the data post-facto and tabulated, a sample is provided in Table 2.

Table 1 below shows the assumptions and formulas that make up the computational input to the KT calculator that in combination with the output of statistical analysis and variables listed in table 3 provides the output shown in the four graphical displays two of which display results for the wireless statistical data and the other two displaying that of the non-wireless statistics.

Table 1

Assumption 1:	Kr / Kt = 60/40 hence Kt=.4 and Kr =.6 and based on Y = mx + b where b = 0 for wireless and b =1 for non-wireless values
Assumption 2:	values Kt and Kr are normalized to read in minutes hence x60 from given values in hours from survey data
Assumption 3:	value Qk = coefficient of correlation uniformly applied to MTTR values to account for MSC staffing levels
Type Values:	**FORMULAS**
Function	**Qt=*f*(kt,kr);** where f = percent of wireless and non-wireless use
IV	**Kt=Qt x t x .4** (instantaneous knowledge transmitted)
IV	**Kr=Qt x t x .6** (instantaneous knowledge received)
IV	**MSC factor =((100-(MTTR /Total MSC staff))x.01)x((MTTR-(Qk x MTTR))**
Constant	**Qk=r(coefficient of correlation)** between **MTTR, KT**
DV	**KT=Kt + Kr** (cumulative knowledge production)
DV	**MTTR** = (***f*** **x BTS Repair time)/'Avg BTS Repair Cycle) x 60) x Qk**
STEP 1 - Identify total knowledge transfer **Qt** per carrier during BTS repair and transpose to table	
STEP 2 - Calculate Kt for each carrier from values in survey table from tab1 and normalize to minutes from hours given	
STEP 3 - Calculate Kr from values in survey table in tab1 already expressed in minutes	

Table 2

WIRELESS-ENABLED KT CALCULATIONS								
	f **=**	**Qt =**	**MSC**	***K*t =**	***K*r=**	**KT=**	**MTTRi**	**Qk=r**
Carrier #1	0.80	11.2	359	269	403	672	672	0.30
Carrier #2	0.85	13.2	281	316	475	791	494	0.30
Carrier #3	0.90	16.2	150	389	583	972	540	0.30
Carrier #4	0.80	13.5	295	324	486	810	506	0.30
Carrier #5	0.85	13.4	290	321	482	803	536	0.30
Carrier #6	0.90	14.3	204	344	516	861	506	0.30
Carrier #7	0.95	15.1	115	363	545	908	568	0.30
Carrier #8	0.85	15.3	225	367	551	918	612	0.30
NON-WIRELESS-ENABLED KT CALCULATIONS								
	f **=**	**Qt =**	**MSC**	***K*t =**	***K*r=**	**KT=**	**MTTRi**	**Qk=r**
Carrier #1	1.20	16.8	641	403	605	1008	1008	0.026
Carrier #2	1.15	17.8	490	428	642	1070	669	0.026
Carrier #3	1.10	19.8	171	475	713	1188	660	0.026
Carrier #4	1.20	20.3	558	486	729	1215	759	0.026
Carrier #5	1.15	18.1	493	435	652	1087	725	0.026
Carrier #6	1.10	17.5	292	421	631	1052	619	0.026
Carrier #7	1.05	16.7	132	402	602	1004	628	0.026
Carrier #8	1.15	20.7	293	497	745	1242	828	0.026

Table 3 Sample statistical output obtained from one set of tested outcomes

WIRELESS SUMMARY STATISTICS							
IV Values	**N**	**Mean**	**Std Dev**	**Variance**	**Std Error**	**Kurtosis**	**Skewness**
Kt (sender)	8	346	27.54	759	10.41	-1.39	0.39
Kr (receiver)	8	520	10.41	1707	15.62	-1.39	0.39
MSC (total personnel)	8	223	71.12	5058	26.88	-1.34	-0.51
DV Values	**N**	**Mean**	**Std Dev**	**Variance**	**Std Error**	**Kurtosis**	**Skewness**
KT (total output)	8	866	68.86	4741	26.03	-1.39	0.39
MTTR (time to repair)	8	537	41.40	1714	15.65	0.48	0.99
NON-WIRELESS SUMMARY STATISTICS							
IV Values	**N**	**Mean**	**Std Dev**	**Variance**	**Std Error**	**Kurtosis**	**Skewness**
Kt (sender)	8	449	36.57	1337	13.82	-1.88	0.17
Kr (receiver)	8	21	54.85	3008	20.73	-1.88	0.17
MSC (total personnel)	8	347	168.10	28256	63.53	-1.90	-0.01
DV Values	**N**	**Mean**	**Std Dev**	**Variance**	**Std Error**	**Kurtosis**	**Skewness**
KT (total output)	8	1123	91.41	8356	34.55	-1.88	0.17
MTTR (time to repair)	8	698	76.27	5817	28.83	-0.35	0.79

3. Statistical analysis

Regression analysis was the preferred statistical method with which to test the model for two very important reasons. One is that linear regression though somewhat generic is a robust modeling method applicable to many different types of models and fields of study. Second and more importantly is the fact that it utilizes a wide range of well-established and proven statistical properties and as such offers a plethora of valuable graphical and numerical output with which to view and analyse data. The independent or predictor variables for the analysis were KT and MSC and a dependent variable MTTR. ANOVA results were used to test the null hypotheses. Although the real power of ANOVA lies in the ability to compare multiple means and variances another advantage is in displaying a wide range of results within a limited set of target test variables. Tables 5.0 to 6.0 summarize results associated with the predictor variables to include the t and F values, squared structure coefficients and adjusted R, and ρ(rho) values which underpin the probability of whether or not a null hypotheses are to be rejected or accepted. By convention values of $\rho < .05$ (95% confidence) result in rejection of a null hypothesis and the result declared statistically significant making ρ the most critical. In addition to the aforementioned, ANOVA is also able to show and explain significant differences between data sets.

4. Conclusion

The main goal of this study was to develop, explore and apply a model that provides a means by which to quantify and measure knowledge transfer between a source and receiver in a mobile environment. To clarify again the sources and receivers in a KM-specific context are the new-age knowledge workers discussed earlier in this paper. It is therefore hoped that this effort will expand the framework and definitions for KT as a valid subset of KM and perhaps add to the existing body of research and literature in so doing. The preponderance of research data in KM and KMS researched to date however were found to be mostly content-based and firm-centric and thus either descriptive or prescriptive with regard to how, when, where, and for whom to harness knowledge. In that regard therefore this research helps illuminate the dilemma faced by modern firms today as based more on how much and quite often how quickly knowledge already acquired and available can be transferred, executed within and then converted into actionable intelligence by an organizational KMS

In the final analysis the KT variable was a major predictor of all outcomes, measurement criteria and computational engines also for the other predictor variables, MSC, Kt and Kr. The MTTR therefore clearly performs as the primary dependent variable and thus the object upon which the predictor variables acted on toward a measureable result. Further, evidence that U.S. MSC operators are routinely engaged in knowledge transfer during repair and maintenance of base station transceiver systems (BTS) was confirmed by the data obtained in this study. The results from this study also suggest that in accordance with Davenport et al (2002), portable wireless technology in this case, did in fact play a major role in KT for MSC operators and as such may substantially reduce total time and resources they need to invest in operations and related expenses. The goal of this study was thus fulfilled by successful application of a model for the "right system of measurement" to use in conjunction with a wireless delivery modality ensuring the right information was exchanged between the right persons at the right time (Pearson, 1999). The results also demonstrated the extent to which both independent and treatment variables influenced KT and thus the degree to which they are reliable predictors of MTTR as well. Furthermore, the test results showed a high correlation between mathematical relationships and formula constructs used to develop the descriptive statistical framework while others produced multi- collinearity effects in the predictor variables for both source and receiver.

The context-specific nature of the knowledge transferred also played a major role in determining source-receiver interaction and ultimately reductions in MTTR in proportion to increases in KT, Kt and Kr. The results nevertheless still may not reflect or explain any pre-existing or explicit knowledge on the part of source or receiver nor causal effects of any outliers or exigent variables not included in the analyses possibly requiring more measurements to be made over time. In addition slope offset of the regression line for non-wireless KT and MTTR indicated probable insufficient non-wireless utilization levels for the treatment variables to be able to respond to. This was found to be true for telecommunications service providers routinely engaged in the maintenance and operation of systems that support multiple modalities such as multimedia communications in which wireless service providers now make up the vast majority (Umar, 2004). As such non-wireless utilization levels are not surprisingly low enough that the resulting statistics yielded a low Beta weight value for KT despite the presence of multi-collinearity effects for independent variables Kt and Kr. Hence the scores for Kt and Kr also understandably show little if any effect on the MTTR not only as a function of low usage but also from the low level of source-receiver interaction resulting from all interactions.

Given that MTTR in this study relates input to output device utilization levels as a function of KT the MTTR serves as a primary determinant of and an expression for BTS repair rates. Moreover the wide variances in source to receiver data in the presence of non-wireless modes along with a relatively high correlation appearing in the Kt, Kr, and KT relationships, further underscores the significance of the findings of the research and tested outcomes.

The MSC staffing variable successfully quantified the frequency and level of personnel activity during a BTS repair cycle as expressed by variables Kt and Kr for KT behavior and outcomes. The influence of the MSC predictor variable is underscored by the significant contribution it makes to the known variances with a score above 60% underpinned now by personnel factors previously unaccounted for in analyzing MTTR outcomes. Hence this finding supports the existence of valuable synergy among the elements of both the informational and organizational infrastructure linking knowledge resources and thus knowledge to the end users. The result is a higher knowledge output and moreover the probability of a faster problem solving capability somewhat implied by the lower MTTR in the wireless versus non-wireless statistic.

The Deming/Shewhart PDCA cycle or Plan-Do-Check-Act process for continuous improvement also demonstrates how the integration of business, technology, and human elements interact in such a way as to enable organizational staff and management to recognize and resolve problems more quickly and effectively (Pearson, 1999). The variation in the predictor variables in this study support findings by Szulanksi (2003) with regard to differences they display at different times and points over the measurement interval and consistent with his developmental model. In this study also the experience of the respondents was not measured and assumed to be equal across the total number of those surveyed. Ruggles, (1998) posited however, that effective transfer within organizations while usually dependent on some type of technology is fundamentally a function of the dissemination and recombination of experience as a function of the transfer. In this regard the question is raised as to how conclusive or substantive the results of this study are or can be without a measure of the how much experience actually contributed to the results. The dichotomy in the findings as such are of particular interest and significance and are a concern as well since the same statistical values may also reflect a high correlation between the KT and MSC variables as shown in the collinearity diagnostics.

In conclusion, introduction of the human element attests to the findings of Pearson, 1999 et al around the idea that technology of itself may be more an accelerator of knowledge transfer than a determinant of the quantity or frequency thereof. Further as in the case of wireless-enabled KT the experience factor while not a direct measurement can be implied in the cumulative effect and changes in MTTR outcomes. Overall the findings related to the MSC and MTTR condition in combination raises a concern specifically with the constructs used in framing both the analysis and the underlying analytical engines.

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