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STRATEGIC MANAGEMENT

MANAGEMENT SCIENCE TOOLS AND OPERATIONAL EFFICIENCY OF PUBLIC UNIVERSITIES IN KENYA

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ABSTRACT

Purpose of the Study: The University landscape in Kenya has experienced increased enrollment and demand for academic output amid diminishing resources prompting operational adjustment towards efficiency. Adoption of management science tools has been proposed as a remedy. However, the concept faces a number of challenges including lack of clear understanding of the dimensions and indicators for measurement of operational efficiency in the University context.

Statement of the Problem: According to World Bank report 2019 on Improving Higher Education Performance in Kenya, 2017/18 global competitiveness index identified fundamental gaps in the quality of graduates transiting from Kenyan universities evidenced by insufficient capacity to innovate, poor work ethics, and an inadequately educated workforce as some of the most challenging factors for doing business in Kenya.

Research Methodology: This study undertook a systematic review of existing theoretical and empirical literature on management science tools, organization capability, organization context and efficiency. The relevant theories and constructs to the study were examined, operational indicators identified and both theoretical and conceptual gaps identified.

Result: Existing literature pointed to successful application of management science tools in efficient management of organizations in other industry though not much research exists in universities.

Conclusion: This paper makes theoretical contributions in management science through inclusion of moderating variable, organization context and mediating variable, organization capability in development of a proposed theoretical model that seeks to guide future studies examining the effect of management science tools on operational efficiency.

Recommendations: This paper recommended an empirical study using the proposed theoretical model in order to establish the relationship between the variables in order to contribute to the body of knowledge on the concept of operational efficiency.

Key Words: *Management science tools, organization capability, operational efficiency, organization context*

INTRODUCTION

The higher education sector in Kenya has experienced tremendous transformation over the past years. This has seen the increase in the number of universities to 74 with 31 public chartered Universities, 6 public constituent colleges, 18 private chartered Universities, 5 private constituent colleges and 14 on Letter of Interim Authority. The changes have also seen establishment of various institutions to support the Government's University agenda. These include transformation of Joint Admissions board to Kenya Universities and Colleges Central Placement Service (KUCCPS) in 2012 with the mandate of placing students in universities and Government tertiary colleges. National Commission for Science, Technology and Innovation (NACOSTI) was also established to promote research in Universities. Public universities control the biggest share of programs, resources and enrollment of students. According to Mukhwana et al (2016), 81% of the programs ran in public Universities while 19% were in private Universities and out of the 539,749 students pursuing university education in Kenya, 83% were in public Universities while 17% were in private University.

According to the Universities Act 2012, public university is a university maintained or assisted out of public funds. According to World Bank (2019). The Kenyan government has made efforts to align higher education system to the national growth agenda through Vision 2030 and 'Big Four Agenda'. The government formulated in 2018 a new five-year education plan (2018–2022), which includes priority areas for investments in higher education. Higher education initiatives in the education plan focus on translating what students learn into labor market demands, with thematic areas around increasing access and equity, improving quality and relevance, and addressing governance and accountability. Priorities outlined in the national education strategy include establishing the Open University of Kenya (OUK); improving retention, well-being, and productivity of university students; and increasing access to science, technology, engineering, and mathematics (STEM) programs. The plan seeks to realize a number of specific objectives including increasing the gross enrollment ratio in university education from 7 percent to 15 percent., enhancing the quality and relevance of training and research, increasing access to STEM programs to 60 percent of the student population, creating opportunities for academic staff to acquire PhDs and appropriate pedagogical skills.

Grow the Open University of Kenya degree programs portfolio to 30 percent accessibility though e-learning mode by 2022, enhance equity and inclusion in university education for the marginalized and underprivileged students as well as strengthen governance and management of university education (World Bank, 2019). These ambitious government plans are coming a midst a myriad of challenges faced by universities in Kenya including declining quality standards and declining government funding against increasing enrollment. According to World Bank (2019), Kenya through Vision 2030 targets to

achieve standards like Southeast Asian 'newly industrializing countries' such as Hong Kong SAR, China; Singapore; Republic of Korea; and Taiwan. Increased access to university education has put Kenya's higher education enrollment rate at 11.7 percent though this is lower than the upper-middle-income economies that Kenya aspires to emulate which are at 70 percent across the programs. Given the scarce resources available to public universities and the importance of the sector to national development, this paper seeks to contribute on how these resources can be used efficiently to produce desired academic outputs.

The study will explore how the selected public universities are applying management science tools to solve complex problems and make efficiency decisions. These tools include decision theory, forecasting, linear programming and simulation. Efficient universities are those institutions using the least amount of inputs per output relative to their peers (Cooper et al, 2007). In this context, we shall consider both technical efficiency and scale efficiency. An entity is technically efficient if it can produce an output without using more of inputs or producing less of other outputs. Scale efficiency is a measure of optimal scale of operation of a DMU which is computed as the ratio of technical efficiency scores under two different scale assumptions. According to Cooper *et al*, 2007, a DMU can operate under increasing returns to scale, decreasing returns to scale or constant returns to scale with the later considered to optimal level of operation. Inputs in this case would include number of faculty, expenditure, number of students, qualifications of faculty while outputs would be the number of degrees awarded and research output. This therefore means that for us to measure efficiency, we should develop a benchmark against which productivity of other decision making units (DMU) can be compared. Productivity in this case refer to the value derived as a ratio of output produced to physical inputs while efficiency in this context is the index used to rank the different productivity values. In the case of higher education, several inputs are used to produce several outputs hence it is advisable to attach relative weights to each input and output to develop their composites in deriving single valued productivity measure (Cooper *et al*, 2007). For instance, a productivity measure could be the number of publications per faculty member.

According to Mukhwana *et al* (2016), increase in the share of government funding to higher education in recent years, from 15.5 percent in 2013/14 to 22.7 percent in 2018/19, has barely kept pace with the increase in the number of public universities and increase in enrollment. This has led to most universities operating deficit budgets. This situation has been made worse by resistance from students at any attempt to increase fees by university management (World Bank, 2019). It is therefore important to assess how efficiently the public universities are utilizing the resources at their disposal since the current funding model is not performance oriented and does not have built-in incentives to encourage the universities to be innovative in the types of programs that they set up or in their curricular and pedagogical practices. Due to disparities in funding per student across public universities through public subsidy which is not based on any objective criteria adds to the need for an efficiency index to guide resource allocation of these institutions (World Bank, 2019).

Table 1: Per-student Government Allocation in Select Public Universities (2017/18)

Universities	Enrollment	Government Budget (KES, millions)	Per-Student Subsidy (KES, thousands)
University of Nairobi	26,009	6,300	242
Egerton University	15,223	2,800	184
Kenyatta University	21,462	3,100	144
Jomo Kenyatta University of Agriculture and Technology	12,029	1,700	141
Technical University of Kenya	8,636	1,070	124
Technical University of Mombasa	4,520	770	170
University of Eldoret	14,275	1,100	77
Machakos University College	5,056	340	67

Source: CUE 2017.

The number of academics teaching at public universities has grown by only 13 percent between 2011 and 2018, while student numbers rose fivefold (World Bank, 2019). Efforts by the government to accelerate the production of postgraduate degree holders to plug in this deficit has been hindered by low PhD enrollment and graduation rates. According to Mukhwana *et al* (2016), PhD enrollment in both private and public university is at 1.3% of the total student's enrollment. Many universities do not have sufficient numbers of qualified staff as evidenced by student-teacher ratios which is about 70:1 in several public universities which undermines the quality of the training offered (World Bank, 2019). According to Kenya National Bureau of Statistics Economic survey 2019, the enrollment in secondary school increased by 4% in 2018, this coupled with government's policy on 100% transition is likely to worsen the lecturer-student ratio in future which currently stands at 1:70 against 1:50 for theoretical based courses and 1:20 for practical-based courses according to CUE guidelines (Mukhwana, 2016). According to a survey by Corporate Staffing Services (2015), Kenya has many unemployed workforces who despite being educated, employers find it difficult to fill key positions with almost three quarters of the respondents (71.8%), receiving too many job applications that require extra time and cost to screen or filter down to find those qualified for the position. The 2013 World Bank Enterprise Survey indicated that close to 30 percent of firms surveyed reported "an inadequately skilled workforce as their most important constraint inhibiting growth." (Mburu, 2014). This points to ill prepared graduates who lack correct skill sets and attitude for the job market (Youth Impact Labs 2019).

Determination of university efficiency

This study considers number of graduates and research as proxies to measure university output. These two lack standard market price that can be used to assign weights while carrying out the analysis. The number of graduate's measure is best considered over a given

number of years and not for measuring one-year output (Cooper et al, 2007). Given the established admissions criteria under CUE guidelines (2012., Rev. 2016), students joining the public universities have similar entry behavior hence it can be assumed that they have more or less similar background or abilities as well as equal access to inputs justifying homogeneity of DMUs. Data Envelopment analysis has been proposed as a technical of assessing technical efficiency of the Universities as decision making units (Alabdulmenem, 2016).

STATEMENT OF THE PROBLEM

According to World Bank report 2019 on Improving Higher Education Performance in Kenya, 2017/18 global competitiveness index identified fundamental gaps in the quality of graduates transiting from Kenyan universities evidenced by insufficient capacity to innovate, poor work ethics, and an inadequately educated workforce as some of the most challenging factors for doing business in Kenya. The Commission for University Education (CUE) closed campuses and recalled PhDs awarded due to quality concerns which is a sign of inefficiencies in the system. Quality is still at stake going by the high student-lecturer ratio at 70:1, projected future increase in enrollment due to increasing enrollment in secondary schools as well as increase in the number of programs and campuses against limited resources. Most public universities are in dire financial situations leading to huge deficits. Projected drop in enrolment of self-sponsored students, quantitative expansion by campuses and programs against limited resources and competition from private universities demand operational efficiency of public universities to continue in existence. Comparative studies of efficiency in public universities will yield an efficiency index that will guide prioritization and value based allocation of resources, spur positive competition among universities and align university performance to national growth agenda. The efficiency index will also provide objective criteria for differentiation in the public subsidy allocated across public universities against the current practice. This paper therefore seeks to bridge the gaps identified in the theoretical and empirical literature through the proposed theoretical model and provide a basis for future research.

CONCEPTUALIZATION OF KEY CONSTRUCTS

Management Science Tools

Management science is problem-solving through mathematical models that represent simple-to-complex functional relationships and that provide a basis for scientific decision making. It applies various techniques referred to us tools in solving management problems. These include linear programming, forecasting, simulation, decision theory, queuing model, transportation model and assignment model.

Scholars have argued whether application of management science tools in decision making is superior to use of intuition and human judgment. This school of thought was interrogated by Zeleny & Dewey (2017),in the paper entitled “Managers without Management Science” in which they concluded that various management sciecne tools are critical in coming up with quality decisions. In their findings, human judgement has failed to appreciate the role of sample size, insensitive to reliability of information used and expected outcome, full of biases and exhibit systematic and predictable judgemental errors irrespective of length of training or experience.They highly recommended application of management science tools especially linear and decision models. This paper proposes to

examine the relationship between linear programming, forecasting, simulation and decision theory and operation efficiency. According to Gupta & Hira (2012), linear programming was developed in 1947 by George Dantzig and his associates as a technique for solving military planning problems while working on a project for U.S Air force. It involves representing the various activities of an organization as a linear programming model by minimization or maximization of a function of variables known as objective function. The objective function may be profit, cost, production capacity or any other measure of effectiveness possible of being optimized. Constraints necessitating optimization may result from limitations of resources like market demand, production process and equipment, storage capacity, financial resources among others. A number of assumptions should be considered when applying linear programming (Gupta & Hira, 2012).

Forecasting is the projection of the past data into future through extrapolation or generalization with desired level of certainty (Gupta & Hira, 2012). The concept of forecasting can be utilized by managers when planning for future resource requirements and demand. To do accurate forecast, the manager should clearly understand the options at his or her disposal and the appropriate time scale. This will guide on whether he or she should do a short term, medium term or long term forecast in a way that results in optimal decision. The concept of forecasting can help the universities to manage enrollment and resource planning. According to Williams and Nolan (2001), the two main approaches to forecasting are qualitative and quantitative. A qualitative approaches include panel approach, the Delphi method and scenario planning while qualitative methods are time series analysis and causal modelling techniques (Gupta & Hira, 2012).

The concept of simulation has been used widely in complicated problems of managerial decision making by testing a number of policies without disturbing the real system. Simulation is a representation of reality through the use of a model or other device which will react in the same manner as reality under a given set of conditions (Gupta & Hira, 2012). Simulation can therefore refer to imitation of reality either in the physical form, computer programming or mathematical equation. Simulation has been found to present a number of advantages when used for decision making regarding new processes, complex situations and situations of flexibility. Some managerial decisions are too delicate, risky and complex to be carried out on a real system. Simulation is also able to bring out the difficulties and challenges associated with a new process or product hence eliminating costly trial and error. In addition, simulation is considered superior to mathematical analysis and is comparatively flexible allowing modifications in the test environment. (Williams & Nolan, 2001).

In the day to day operations of businesses, managers are faced with uncertainties and the need to make correct decisions. Decision theory empowers managers to make decisions under conditions of uncertainty. Decision makers must function in three types of environments. In each of these environments, knowledge about the states of nature differs. Decision making under conditions of certainty, only one state of nature exists as complete certainty about the future (Gupta & Hira, 2012). In decision making under conditions of uncertainty, more than one state of nature exists, but the decision maker has little knowledge about the various states and is unable to assign any probability for their occurrence. The criteria for decision making includes Maximax criterion, Maximin

criterion, Minimax Regret criterion, Huwicz criterion and Laplace criterion. Finally, in decision making under conditions of risk, more than one state of nature exists but the decision maker has information which will support the assignment of probability values to each of the possible states. Decision making is guided by expected value criterion and expected opportunity loss criterion (Gupta & Hira, 2012).

Efficiency

The word efficiency in this context is defined in relation to productivity whereby Productivity is a value assigned to the rate at which inputs are converted into outputs and efficiency is a ranking of different values (Munoz, 2016). The inputs here may be in physical quantities or nonphysical in nature. For instance, the input measure in a university scenario could be expenditures on instructional activities and output be the number of educated students, then the productivity measure becomes the number of students educated per dollar spent on faculty to yield faculty expenditures per student as a cost-based productivity measure (Salerno, 2003). Ranking of this productivity measure assesses the cost efficiency of each institution relative to the others being evaluated. There are four key types of efficiencies in the context of higher education namely technical efficiency, allocative efficiency, overall efficiency and scale efficiency (Munoz, 2016). Technical efficiency is a measure of the extent to which an institution efficiently allocates the physical inputs at its disposal for a given level of output (Salerno, 2003). Entities using the least amount of inputs per output are regarded as efficient relative to their peers.

Allocative efficiency incorporates the cost factor by considering how different input combinations can be traded off given a fixed budget for optimal efficiency (Munoz, 2016). It brings to light the extent to which inefficiency occurs because an institution is using wrong mix of inputs when cost is put into consideration (Salerno, 2003).

Overall or economic efficiency combines both technical and allocative efficiencies in assessing efficiency. Scale efficiency is underpinned in principles of economics in which entities are either operating at increasing returns to scale (IRS), decreasing returns to scale (DRS) or constant returns to scale (CRS) (Munoz, 2016). An efficient entity is one that operates at constant returns to scale. CRS occurs when doubling all inputs results in a doubling of the output. In the case of decreasing returns to scale, doubling the inputs results in a less than equal increase in output. However, if additional inputs results in a greater than equal increase in output then an entity is said to be operating at increasing returns to scale (IRS). Deviations from CRS provide a measure of scale inefficiency and can also provide insight on whether or not an entity is too large or too small. For instance, one lecturer may be able to teach up to 80 students in a class but if the enrollment is low at 40 students in the same class, the lecturer would still teach but the relative cost per student will increase. As enrollments expand, per-student costs decline because the institution does not have to engage more lecturers but the output will increase (Salerno, 2003).

Efficiency Index

Data Envelopment analysis (DEA) has been applied widely in measuring efficiency of entities especially universities in different continents. However, not much of such studies have been carried out among universities in Kenya.

Alabdulmenem, (2017), carried out research to measure efficiency of public universities in Saudi Arabia using Data Envelopment Analysis. The input variables included faculty and administrators while output variables were number of new entrants, number of enrollees and number of graduates. Weights of each DMU were generated and related efficiency scores. Out of the 25 Saudi Arabian Universities under study, 15 of them were operating under perfect efficiency while 10 recorded different levels of inefficiencies. He however noted that DEA is used to measure the efficiency of like and comparable decision-making units (DMUs) relative to one another hence should only be interpreted in the context of DMU under study (Alabdulmenem, 2017).

A study by Munoz (2016) estimated technical efficiency of 43 private and public universities in Chile from 2013 to 2014 and his findings were that public higher education institutions were more efficient relative to private higher education institutions. In a study of efficiency of public universities in Colombia, Visbal-Cadavid, Martínez-Gómez, and Guijarro (2017) analyzed the efficiency of 32 public universities in Colombia and concluded that over 50 per cent of universities were efficient while the rest were at different levels of efficiency.

Quiroga‐Martínez et al (2018) studied efficiency in public higher education in Argentina in which out of the thirty-three universities of social sciences studied, nine were fully efficient with efficiency index of 1 while the rest recorded different levels of efficiencies with the lowest recording 0.41. The study considered total number of researchers and statutory grant as inputs while output comprised of total number of students, total number of publications and total value of externally acquired fund.

Myeki & Temoso (2019) undertook a Panel Data Evidence in carrying out the efficiency assessment of public Universities in South Africa between 2009–2013. The inputs considered in DEA were staff numbers, students' enrolments, and expenditure while outputs were number of graduates and publications. The results indicate that over the study period the average technical efficiency (TE) of universities declined from 0.83 to 0.78. In addition, the study revealed that research-intensive universities were more efficient than professional-oriented universities (Myeki & Temoso, 2019).

AL-Tyeb (2017) studied the efficiency of 15 public universities in Egypt using DEA for the year 2013/2014 and found average efficiency of 0.53. His studies identified 47 per cent potential to improve outputs from the universities under study to achieve optimal efficiency. Similar study in East Africa was carried out by Bangi (2014) in which he applied a two-stage DEA approach method to determine technical efficiency of private universities in Tanzania for the years 2008 to 2012, and found average technical efficiency of 0.93 with only 7% room for improvement to realize optimal technical efficiency. Collectively, these research employ DEA in assessing efficiency of universities with emphasis that DEA is used to measure the efficiency of like and comparable decision-making units (DMUs) relative to one another hence it can only measure relative efficiency of DMUs under study. In addition, Economic theory on efficiency analysis is used for selection of performance indicators in the reviewed studies (Quiroga‐Martínez *et al*, 2018, Myeki and Temoso, 2019, Alabdulmenem, 2017). It is therefore imperative that a separate study in Kenyan context be carried out to measure the efficiency levels of universities in Kenya applying economic theory of efficiency.

THEORETICAL REVIEW

Scientific Management Theory

Frederick W. Taylor (1856-1915), an American Engineer and inventor is considered the father of scientific management. In his works, he came up with four principles namely research, standardization, control and cooperation to guide systematic approach to problem solving. The theory advocates for utilization of scientific, engineering and mathematical analysis to improve organizational efficiency by improving efficiency of individual task completion (Vijai, et al (2017). His theory focused more on application of systematic procedures by organizations to deliver quantitative outputs. Vijai, et al (2017), investigated the relevance of F.W. Taylor's principles to modern shop-floor practices and concluded that the current management science practices are anchored in the original works of F.W Taylor. These principles are considered relevant to the study at hand.

Pareto Efficiency Theory

Pareto's efficiency theory was developed by Italian economist and engineer Vilfredo Pareto. He theorized it as an economic situation when the circumstances of one individual cannot be made better without making the situation worse for another individual. Pareto's efficiency takes place when the resources are most optimal hence some scholars have considered it as the best scenario in theory but with limited practical application (Kreps, 1990). It is commonly used in the context of welfare economics, where two or more individuals are endowed with various goods. It addresses the individuals' desire to maximize utility and trade goods with each other at the market price to arrive at an optimal allocation of goods. When the market price is assumed to be exogenous and all individuals are price takers, then the state of optimality is known as a Partial equilibrium (Kreps,1990). If the market price is endogenous or determined in conjunction with the production process, then the state of optimality is known as a general equilibrium. Applied in the context of this study, Pareto efficiency can be applied in balancing competing attention for resources among DMUs in a university which could be departments, faculty or government capitation among public universities themselves. Pareto efficiency frontier on feasible resource tradeoffs forms a basis for development of efficiency frontier in this study.

Kaldor-Hicks Efficiency

This theory builds upon Pareto efficiency on efficiency in allocation and reallocation of resources where any change in reallocation of resources produces more positives than negatives with respect to costs. i.e. there are more resultant benefits than costs by sufficient compensation from those who are made better off to those who are made worse off so that all would end up no worse than before. This phenomenon is referred to as Kaldor-Hicks efficiency(Wang et al., 2018). According to (Posner, 2007), this theory forms the basis of modern cost-benefit analysis and is considered more of wealth maximization than utility maximization. He argues that it is the best tool that policymakers possess to judge the merits of policies or public projects, which involve transactions between willing and unwilling parties (Posner, 2007), unlike Pareto which may not be practical, the Kaldor-Hicks criterion is considered more pragmatic than Pareto because it forces the decision maker to confront the cost-benefit of a particular policy or project so that even if the issue

is not addressed at present, way forward is arrived at on how to address it in future putting into perspective present and long term cost benefit analysis of a decision (Ellerman, 2014).The criterion is not devoid of shortcomings as it relies heavily on wealth and utility maximization, the distributional effects of a policy are ignored in favor of total benefits. However, it is possible that the benefits and costs are interpreted differently under wealth maximization and utility maximization (Posner, 2007). The theory promotes the concepts of cost benefit analysis and utility maximization which are elements of efficiency. Decision theory considered in this study has a place in helping to come up with the most optimal decision.

PROPOSED THEORETICAL MODEL

From existing literature on management science tools and efficiency, several dimensions emerged that forms a basis for developing new theoretical model consisting of the construct of management science tools and efficiency. The existing literature are consistent in indicators for measuring efficiency hence the indicators used in this study have been derived from conceptual, theoretical and empirical studies.

Organization context is considered in this study to have a moderating effect since universities operate in open environments and are subjected to the dynamisms in the environment in which they operate in. The organization context issues include the statutory and regulatory requirement, competitive landscape, resource availability, organization culture and organizational strategy (Muthimi & Kilika, 2018).

The paper has considered organization capabilities as a mediating construct as it determines that ability and likelihood of an entity to apply management science tools in a way that will affect the resulting efficiency.

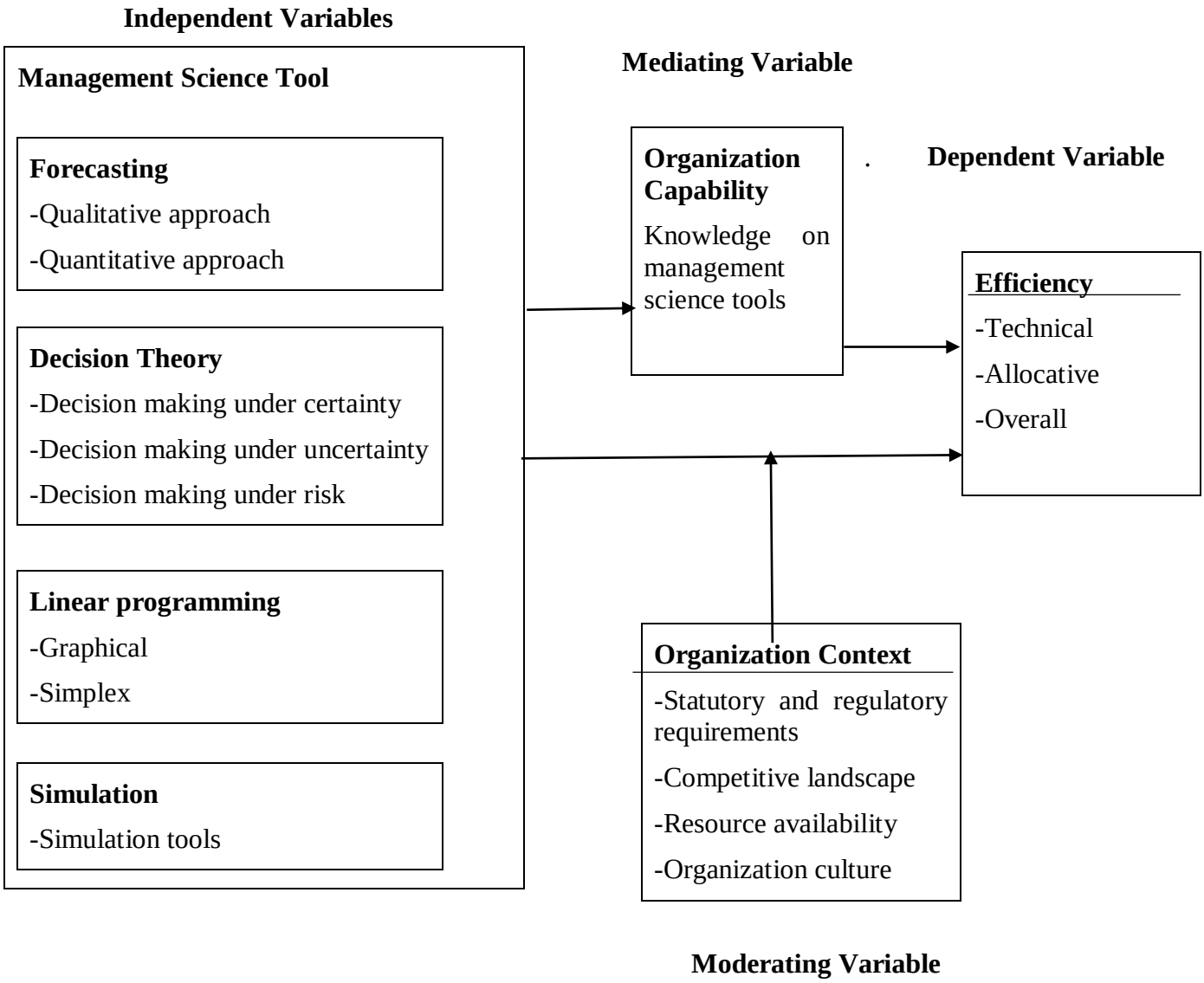

Figure 1: Proposed Theoretical Model linking Management Science Tools and Operational Efficiency

Proposed research propositions

From the proposed theoretical framework, it is further proposed that an empirical study be carried out with management science tools as an independent variable and operational efficiency as a dependent variable, organization capabilities as a mediating variable while organization context as a moderating variable. This study will be guided by the following four propositions;

Proposition 1: Application of management science tools will affect positively the various dimensions of operational efficiency.

Proposition 2: There is a correlation between deployment of management science tools in management of public universities and the capabilities exhibited by the universities managers.

Proposition 3: Organizational workforce capabilities will mediate the relationship between applied management science tool and the resulting operational efficiency.

Proposition 4: The relationship between management science tool and operational efficiency will be moderated by organization context affecting the ability of the leaders to achieve the intended level of efficiency.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to examine the concept of management science specifically its tools and the application in managing organizations efficiently. From the review of existing conceptual, empirical and theoretical literature, it has been observed that extensive research on measurement of efficiency has been done in countries other than Kenya to arrive at relative index which is only applicable to the DMUs under study in the specific countries. Existing literature also points to successful application of management science tools in efficient management of organizations in other industry though not much research exists in universities.

Management science tools is argued to improve efficiency through scientific and objective decision making beyond intuition and human judgment putting into consideration the mediating role from organization capabilities and the moderating effect of the organization context in which the organization operates in. From the above proposed theoretical model and propositions, the author suggests further future research on this area of study including their operational indicators and the direction of relationships as indicated in the proposed propositions through development of suitable measuring instruments for collecting primary data and application of suitable statistical techniques to confirm these hypothesis.

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