BUSINESS PROCESS RE-ENGINEERING: A SOLUTION FOR SOLID WASTE MANAGEMENT IN THE NORTH WEST PROVINCE OF SOUTH AFRICA

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ABSTRACT
This study recognised the dynamic environment in which organisations operate and the imperative for them to innovate in order to avoid failure. It also noted that the current solid waste management (SWM) practice in the North West province was unsustainable and as such, needed to be re-engineered. For that matter, the aim of this study was to formulate a new approach to SWM based on the principle of business process re-engineering. This aim was realised when the stated objectives of the study were achieved. The resultant and major contribution of this study is a regional logistical framework that incorporates rail and road transportation to provide a cost-efficient integrated waste management system that is sustainable over the long term.
Keywords: Business process re-engineering, landfill, solid waste management, waste.

1 INTRODUCTION

Organisations exist and operate in dynamic environments where internal and external forces determine the way they operate. As such, they need to adjust and adapt to the forces of change in the environment or face possible failure [1]. However, change may not always be implemented as and when the need arises. Collin [2] observes that many organisations are designed to service the needs of administrators rather than the desires of the market resulting in the institutionalisation of customer dissatisfaction as an acceptable cost of administrative convenience that weakens competitiveness and innovation in organisations. One may, therefore, infer that in a dynamic environment, organisations that fail to implement change and innovation will not be able to sustain operations in increasingly competitive markets. The two main types of organisational transformation experienced in the business environment are the evolutionary and revolutionary changes. According to Smit *et al.* [1] and Collin [2], evolutionary change is gradual and its impact is localised in particular sections of the organisation, whereas revolutionary change is radical and may necessitate the re-structuring of the entire organisation. The discussion in this paper is delimited to business process re-engineering (BPR), a type of change herein proposed as the solution for improvement of solid waste management (SWM) in the North West (NW) province.

1.1 Background

The NW province of South Africa is located on the fringes of the Kalahari Desert and lies in the south-east quadrant between longitudes 22°30′ and 28°30′ and latitudes 24°30′ and 28°. It borders the Republic of Botswana in the north and the provinces of Limpopo, Gauteng, Northern Cape and Free State [3]. The NW covers a surface area of 116 320 km^2 and has 21 local municipalities [4]. Kadama [5] notes that 87% of the local municipalities in the NW are rural and have small revenue bases. Most of them depend on funding from the central government to finance their capital and operational budgets.

The NW Provincial Integrated Waste Management Plan (PIWMP) is presented as a series of eight goals: Goal 1 is minimum service standards and cost recovery, Goal 2 is landfill licensing, Goal 3 is

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organic waste treatment or composting, Goal 4 is recycling, Goal 5 is rural waste management, Goal 6 is hazardous waste management, Goal 7 is monitoring, risk assessment and remediation and Goal 8 is education and awareness [6]. The PIWMP ascribes to the principles of the waste management hierarchy (WMH). The WMH views waste as a resource that should be reused, recycled or used for energy recovery and not merely a residue which has to be discarded.

According to Kadama [5], SWM services were available in 18 of the 21 local municipalities in the NW with waste collection services available to 86% of the households in the province. Given that waste management is a public good and as such non-excludable to any section of society, Kadama [5] notes that in this respect, waste management in the NW fails to comply with international best practice. The evidence adduced in Kadama [5] indicates that none of the municipalities in the NW had put measures in place to promote sorting at source, composting, reuse, recycling and waste to energy programmes. This implies that SWM in the province is steeped in the unsustainable practice of collection and disposal in landfills. However, the trucks used in the collection and transportation of solid waste conformed to internationally accepted standards in all the municipalities with SWM services [5].

Moreover, investigations in Kadama [5] reveal that of the 42 landfills in the province, the majority (61%) were controlled landfills, 29% were open dumps while 10% were sanitary landfills. Controlled landfills may mitigate surface water and air pollution but are unable to prevent groundwater pollution. On the other hand, sanitary landfills are designed to minimise air and surface water pollution and to prevent groundwater contamination. This situation where only 10% of the landfills comply with international best practice is untenable. In Kadama [5] it is further revealed that all open dump landfills did not have permits and while the controlled landfills had permits, their operations did not comply with their permit requirements. Insofar as operational time left before the landfills were due for closure was concerned, there were no records available for 13% of the landfills, 11% were due for closure but were still operational, 66% were left with 10 years or less and 10% were left with more than 10 years. It also emerged that 82% of the municipalities had plans to construct at least one landfill in the next 10 years. The cost of constructing a landfill is determined by a number of factors including size, ground conditions and type of waste to be landfilled. As this study progressed, Rustenburg Local Municipality was busy constructing a R25 million (US$3 million) sanitary landfill. If each of the municipalities that indicated need for landfills was to construct a landfill similar to the one in Rustenburg, the total capital outlay to new landfills would be at least R425 million (US$53 million). Without a doubt, the management and operation of waste disposal facilities in the NW is not sustainable and needs to be improved.

Regarding the SWM capability of the human resource, investigations in Kadama [5] revealed that 67% of line managers responsible for SWM were suitably qualified for their positions. The problem herein is that in one-third of the municipalities in the NW, decision-making on issues that could have disastrous environmental consequences was entrusted to non-specialists in environmental management. Best practice requires that environmental management decisions should be left to specialists that are capable of holistically assessing the variables in SWM and thereafter make informed decisions. Kadama [5] further notes that in 71% of the municipalities, the job titles of the senior managers responsible for SWM did not allude to the function of waste management. These municipalities had functional organisation structures where SWM was a sub-function of either the engineering or health department. Such an arrangement would not enhance SWM as the attention and effort of functional managers may be consumed by activities in their other sub-functions. As a consequence, the line managers in SWM are likely to be frustrated if their needs are not adequately articulated to other functional managers or the chief executive officer. One may therefore argue that the organisational structure in the municipalities does not promote the objectives of SWM.

In regard to the capital assets and financial aspects of SWM in municipalities, Kadama [5] revealed that the majority of municipalities were severely under-funded and only 30% of the municipalities could finance their SWM recurrent budgets through cost recovery. This situation is not sustainable. Furthermore, the investigations in Kadama [5] also revealed that insofar as enforcement of waste management bye-laws in the NW was concerned the majority (65%) of municipalities did not have effective bye-laws, 65% of the municipalities had officers appointed to enforce waste management bye-laws while 20% had none and 15% relied on their traffic officers. In all municipalities investigated, it was revealed that the cost of prosecuting waste-related malpractices by far outweighed the fines paid. It emerges that municipalities pay salaries for officers who are ineffective due to lack of effective bye-laws. Consequently, illegal dumping becomes rampant much to the consternation of rate paying residents. One may, therefore, argue that the enforcement of waste management bye-laws is an unworthy cost to the municipalities and should be stopped forthwith. However, this recommendation is untenable for, if implemented, illegal dumping and other waste-related malpractices are bound to continue unabated and with impunity.

1.2 Problem statement

From the background, it emerges that SWM in the NW contravenes the strategic objectives of the WMH; waste management activities in the 21 municipalities are carried out in silos resulting in unnecessary duplication of effort and expenses and by using state-of-the-art waste collection trucks, municipalities are using technology as an enabler in an unsustainable practice. Therefore, there is a need to re-plan and implement changes in SWM in the NW.

1.3 Aim of the study

The aim of this study was to present a new approach to SWM in the NW based on the principle of BPR. The re-engineering was expected to result in an integrated and cost-effective waste management system that would exploit regional facilities to increase efficiency.

1.4 Objectives of the study

In order for BPR to be achieved in SWM, the invent phase requires that all the processes ought to be assessed and redesigned where necessary. However, this study was conscious of the advice by Chase *et al*. [7] that not all major processes should be re-engineered at the same time. For that matter, the study opted to confine itself to the re-engineering of the value-adding activities of SWM in the NW and adopted the following objectives: establish the value-adding activities undertaken in SWM in the NW and suggest changes to the *status quo,* estimate the quantity of municipal solid waste (MSW) generated in the province, determine the distances between the towns with existing sanitary landfills and the main towns of the other municipalities and develop a framework that optimises the location of waste management facilities in the province.

1.5 Delimitation of the study

The scope of the study was delimited both geographically and in terms of content. Geographically, the study was confined to the 21 local municipalities of the NW while with regard to content it concerned itself with value-adding activities in SWM in the province.

1.6 Assumptions of the study

It was realised that some important information required for this study was not available because other relevant studies had not yet been conducted. It was therefore deemed necessary to make the following assumptions: all municipalities had enough funds to acquire necessary vehicles and equipment, build transfer stations and implement the statutory remedial procedures prescribed for the closure of landfills. It was also assumed that commercial waste generated in respect of an individual in a population would be 20% of the domestic waste per capita (DWPC) of that population and that the DWPC would remain at 0.572 kg/day as was determined in Kadama [5]. Furthermore, it was assumed that MSW transported to landfills consists of domestic and commercial waste only; the existing sanitary landfills in the province have the capacity to accommodate its MSW load for the next 15 years and waste transportation trucks move at an average of 70 km per hour. These assumptions are based on findings by Cointreau [8].

2 FORCES THAT INFLUENCE ORGANISATIONAL CHANGE

A number of forces from both the internal and external business environments drive change within organisations. These forces may be technological, socio-economic or ecological in nature. Their stimuli precipitate changes in the business environment that results in increased competition, increased productivity, demand for better quality products and services, threats and opportunities. In direct response, organisations may adopt new visions and missions, change strategy, restructure or re-engineer [1].

According to Dettmer [9], organisations operate as systems and not as isolated processes. A system is a group of independent but inter-related elements comprising a unified whole while a process is a sustained phenomenon characterised by gradual changes through a series of states [10]. This implies that in a process, the flow of events is unidirectional. During the course of a process, a later event would not in any way influence an earlier event, but the opposite may be possible. However, in the case of a system, the individual elements or units in a system affect each other's performance and consequently the overall performance of the organisation. In a system, there is a feedback mechanism that makes the system self-regulatory [11].

Cybernetics is the science of control and communication, in animals and machines [12]. From the definition and operations of a system, one can infer that systems are cybernetic in nature. According to Thellefsen and Thellefsen [11], cybernetic systems are comprised of an input, throughput and output with effectors to the environment that activate a feedback mechanism. It is this feedback mechanism that brings about the control function in organisations. Conway and Siegman [12] argue that a control mechanism triggers feedback cycle in a manner where output (action) influences input (perception), in such a way as to bring the action as close as possible to the targeted goal. Cybernetics ensures that all forms of goal-directed action are based on such cycles. It is implied that cybernetic systems are dynamic and they evolve with the environment. Organisations are cybernetic systems because they have a capacity to self-adjust [9]. Therefore, depending on the level of efficiency in the relaying of information in the feedback cycles, organisations may thrive or die in their environment. This implies that the ability of an organisation to achieve its goals is a function of how well the individual elements in its system interact with one another. For this reason, Dettmer [9] argues that organisations are analogous to chains. Like a chain, an organisation's performance is limited by the performance of its weakest link. This means that no matter how much effort is put into improving the different activities of an organisation, only the improvements to the weakest link will produce any detectable system improvement. The weakest link is the system's constraint [9].

The theory of constraints (TOC) is based on the premise that real systems have at least one constraint; otherwise, the systems would produce unlimited amounts of whatever they were striving for [13]. This implies that systems are never 100% efficient due to inherent inexhaustible constraints. Constraints may be alleviated but never eliminated. According to the Bizmanualz Group [14], the TOC is about thinking in a logical, systematic and structured process with a view of solving a problem. It is about analysing the cause and effect, verifying underlying assumptions and exploring alternatives with the aim of arriving at win–win solutions.

2.1 BPR

The concept of BPR was advanced by Michael Hammer in 1990. He defined BPR as the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance such as cost, quality, service and speed. According to Hammer and Champy [15] and Paper [16], BPR requires rethinking and redesigning business processes to obtain dramatic and sustainable improvements. They argue that BPR offers a solution to business problems, which is both novel and practical as it achieves dramatic improvement in the contemporary measures of performance. From the above, it emerges that BPR is a radical process and not merely business improvising; further, it seeks to redesign the way work is done with the aim of supporting an organisation's vision and mission and reducing operational costs. BPR assesses the organisation's mission and strategic goals and customer needs. This process is guided by questions such as does the mission need to be redefined, are the strategic goals aligned with the mission and who are our customers and what are their needs and wants [8]. It is after such introspection that an organisation is able to decide on the best way of doing what it has to do. The continuing development and application of sophisticated information systems (ISs) and networks observed in the past two decades serve as a stimulus for BPR implementation in organisations. According to Hammer [17], the major challenge for managers is to obliterate non-value-adding work rather than using technology to automate it. Implicitly, Hammer [17] accuses managers of focusing on wrong issues such as using technology to automate outdated processes rather than using it as an enabler for making non-value-adding work obsolete [8]. Indeed leading organisations are increasingly relying on IS to support innovative business processes rather than redesigning the current way of doing work [16, 18].

BPR requires organisations to think both creatively and realistically in order to improve cost efficiency and service effectiveness. Sustainable BPR is feasible if organisations adopt data driven methods in the implementation phase [19, 20]. Al-Mashari and Zairi [21] show that successful BPR projects employ simple methods that can be understood and used by non-technical employees rather than complex techniques that can only be implemented by highly skilled employees. Chase *et al*. [7] outline the seven new rules of doing work proposed by Hammer [17]: Rule 1, organise around outcomes; Rule 2, work should be carried out where it makes most sense to do it; Rule 3, people who collect information should be responsible for processing it; Rule 4, treat geographically dispersed resources as though they were centralised; Rule 5, link parallel activities instead of integrating their results; Rule 6, put the decision point where work is performed and build controls in the process and Rule 7, capture information at source. Often scholars confuse re-engineering with process improvement, downsizing, reorganising and functional fixes. Shin and Jemella [18] provide an insight on the differences. Process improvements or quick hits are low risk, easily achievable efforts that avail immediate payback opportunities. They focus on closing small performance gaps, which results in minor changes that achieve small but meaningful improvements. On the other hand, re-engineering is characterised by dramatic process transformation. Shin and Jemella [18] further emphasise that re-engineering is not downsizing though jobs are often lost; it is not reorganising although structures change; it is not functional fixes although functions operate better and it is not a technology project though technology is critical.

The re-engineering process requires a disciplined approach to the effort. Chase *et al.* [7] propose the following six generic steps: Step 1, state a case for action; Step 2, identifies the process for re-engineering; Step 3, evaluate enablers of re-engineering; Step 4, understand the current process; Step 5, create a new process design and Step 6, implement the re-engineering design. Shin and Jemella [18] note that when IBM was engaged to drive BPR in Chase Manhattan Bank, the generic steps cited above were applied in four phases, namely, Phase 1 – energise, Phase 2 – focus, Phase 3 – invent and Phase 4 – launch. Each phase is explained in detail below.

Phase 1: Energise. During this phase, the drivers of BPR mobilise for action. The need for change is effectively communicated through educational and communication campaigns. Two key messages, the need for action and the vision statement, are articulated. This phase is concerned with strategy and direction setting. It takes ideas based on business and environmental information including customer feedback and transforms them into strategies, operational goals and performance measures [8]. Executive sponsorship is sought, project teams established, project and communication plans drafted and a commitment to initiate the project is made [19]. The energise phase deliverables include executive document to communicate why BPR is needed, project organisation teams defined, a project plan and communication plan [19]. Shin and Jemella [18] estimate that 10% of total project time is allocated to this phase.

Phase 2: Focus. In this phase the *status quo* is analysed. About 30% of total project time is spent on this phase. Shin and Jemella [18] admonish project teams to refrain from spending too much time analysing the current process and the financial and technology components under review. One needs to understand the process – not analyse it. The focus phase is hypothesis driven as illustrated in Fig. 1.

The project team develops hypotheses to be proved or rejected during focus phase analysis. The current process is assessed through gathering and analysing data in order to draw conclusions. This analysis is premised on the assumption that competition among businesses revolves around three axes: cost, value and competence [19]. This implies that a product or service is evaluated in terms of associated cost, functionality (e.g. reliability) and competency (a unique offering). The current

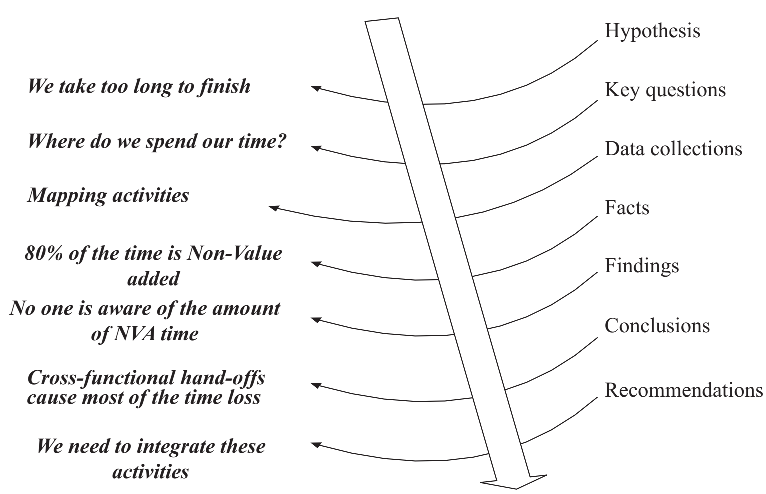

Figure 1: Hypothesis-driven approach of the focus phase. *Source*: Adapted from Shin & Jemella [18].

process must be studied to identify the activities, which are essential for completion of work. Chase *et al.* [7] classify work activities into three types: value-adding work (work for which a customer is willing to pay), non-value-adding work (creates no value for customer but is necessary to get the value-adding work done) and waste (work that neither adds value nor enables value). They advise that value-adding work is essential and as such it cannot be easily eliminated from a process although it can be improved. On the other hand, waste is pointless work whose absence would not be noticed by customers and for that matter needs to be eliminated. However, they argue, non-value-adding work is the glue that binds value-adding work in conventional processes and is therefore necessary. It is mainly administrative overhead such as reporting, supervising and coordinating. It can be a source of errors, delay, inflexibility and rigidity. It is therefore advisable to coordinate value-adding activities in a manner that minimises non-value-adding activities.

According to Chase *et al.* [7], all major processes in an organisation have to be identified and re-engineered based on the following questions that define the criteria for selecting processes for re-engineering: which processes are the most problematic, which processes are critical to accomplishing company strategy and have the greatest impact on the company's customers, which processes are most likely to be successfully redesigned, what is the project scope and what are the costs involved, what is the strength of the re-engineering team and the commitment of process owners and sponsors and is the current process antiquated or is the technology used outdated. The focus phase also needs to pay attention to the current process from the customer's perspective by addressing the following issues: how customers view the organisation and what they want, their willingness to pay for added value, what better value they get from competitors and how best to interact [19]. However, Chase *et al.* [7] caution that not all major processes should be re-engineered at the same time. Simultaneous assessment of process, organisation, financial and information technology components of an organisation is yet another important aspect of the focus phase. The current process should be diagnosed using process evaluation techniques such as flow charts, fishbone diagrams and quality function deployment. This helps to understand its relationship to other processes and identify process improvement opportunities such as eliminating bureaucracy and redundancy, evaluating activities for value add, reducing cycle time, eliminating errors, standardising and optimising supplier relationships [8, 19].

The focus phase also assesses organisation structure-related issues such as organisation mapping, spans of control, staff skills and training, morale and productivity. Typically, functions are organised as silos and resources are allocated to departments. From the re-engineering perspective, the organisation should be viewed across functions rather than as departments or business units [19]. Organisation structure re-engineering would result in an empowered and team-oriented human resource that is process focused.

It is crucial to assess the financial position of the organisation using an activity-based model as it gives planners an insight into what needs to be done while keeping in line with customer needs and wants and the findings of other phases of the re-engineering process. This exercise involves running simulations of the as-is data to identify bottlenecks and value-add/non-value-add steps [19]. As a result, it becomes possible to demonstrate the value of the expected change numerically. Good management decisions are a function of the availability of correct information as and when required. BPR is facilitated by the early identification of information technologies that provide business value. According to Shin and Jemella [18], this includes establishing the value of new information technology, eliminating low-value information technologies and assessing the readiness to implement the new information technologies. The deliverables in this phase include current process diagnosis, characteristics of the current business environment that can be changed or built upon and quick hits or process improvement ideas that can be quickly implemented [19].

Phase 3: Invent. This is a brainstorming session to determine what the redesigned business system should look like and why. According to Shin and Jemella [18], this phase takes about 30% of the entire re-engineering process. It incorporates business and customer perspective considerations along with assessments of the current process, organisation structure, the financial situation and information technologies and envisions how business should be conducted in future.

Phase 4: Launch. This is the ultimate phase of BPR; it takes about 20% of the total project time. In the early stages of the launch phase, care should be taken to identify the tangible and intangible benefits and also the risks associated with the BPR project [19]. Tangible benefits would include impacts on income/expenses, market share, attainment of strategic opportunities and financial metrics while intangible benefits would include customer and employee satisfaction and improved community relations. The BPR model applied in the Chase project calls for an evaluation of project risk factors. This entails a review of project variables such as project size, resource requirements, staffing, time frames, technology capabilities and suitability of existing infrastructure. The preferred position is the selection projects that return high net benefits with low risks [19].

Shin and Jemella [18] aver that an effective process redesign is characterised by responsiveness to executive goals and a fundamental rethinking of how work is done. It begins with envisioning the future process design and is characterised by a time dimension, beliefs and values about the future and models and metaphors describing the way the process should work. The redesign process is bounded by financial limitations, technological capability, certainty of the future and social norms [19]. It pays to note that while there may be similarities in how different firms approach re-engineering, each firm should tailor its BPR effort to suit its unique circumstances [22].

From the review, the model illustrated in Fig. 2 has been developed to serve as a guideline for the envisaged BPR venture. The model depicts BPR as a continuous process. Organisations should continuously strive to minimise operational constraints and non-value-adding work to gain competitive advantages. This is achieved through the feedback mechanism that is inherent in cybernetic systems.

3 RESEARCH METHOD

Different methods were devised to address the objectives of the study. The method adopted for the first objective required one to analyse the activities involved in SWM and identify those that were essential for completion of work. Following advice from Chase *et al.* [7], the activities were classified

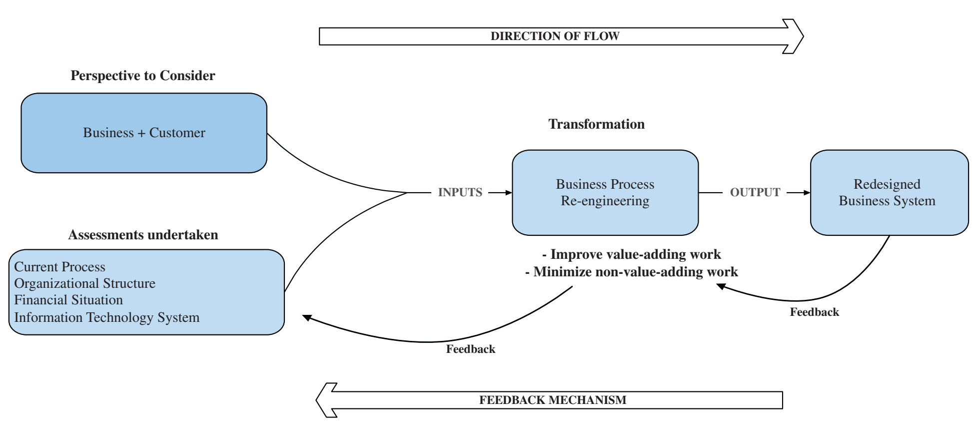

Figure 2: The cybernetic nature of business process re-engineering.

into three categories: value-adding work, non-value-adding work and waste. The criteria used for categorisation were value-adding work is work, which the customers are willing to pay for, while non-value-adding work creates no value for customers but is necessary in order for value-adding work to be done and waste is work that neither adds value nor enables value. Guided by literature reviewed in the introduction and background, value-adding activities in SWM were identified and changes to the *status quo* in the NW were suggested.

To compute the amount of MSW produced on a daily basis in the local municipalities, one needed to know the current population in the individual local municipalities and the DWPC in the NW. The last official population studies conducted in South Africa were the census of 2001 and the Community Survey of 2007. Using the population figures from the two studies, the differential eqn (1) [23] was applied to estimate the population growth rate of the NW and thereafter the estimated population in 2011 was computed.

$$P_2 = P_1\ e^{rn} \tag{1}$$

Where:
e = 2.718 (a constant exponential function)
P_1 = Population in 2001
P_2 = Population in 2007
ln = Natural logarithm
n = The time interval between 2001 and 2007
r = The population growth rate
Solve for r as follows:

$$\frac{P_2}{P_1} = e^{rn}$$

Apply natural logarithms

$$\ln\left(\frac{P_2}{P_1}\right) = \ln(e^{rn})$$

Given that:

$$\ln e = \ln 2.781 = 1$$

Then

$$ln\left(\frac{P_2}{P_1}\right) = rnlne$$

$$r = \frac{ln\left(\frac{P_2}{P_1}\right)}{n} \tag{2}$$

Having established the population growth rate of the province, eqn (1) was applied to estimate the current population in each local municipality (P_3) and the province as a whole. The DWPC of the province was obtained from Kadama [5] and was applied as follows to compute the daily municipal solid waste (DMSW) load in kilogram (kg) of the individual local municipalities:

$$\text{DMSW} = P_a\text{DWPC} + (0.2)P_a\text{DWPC} \tag{3}$$

Data on the DMSW load of the local municipalities were captured on a spreadsheet and multiplied by factors of 7, 30 and 365 to obtain the weekly, monthly and annual MSW loads of each local municipality in the province. By summation, the corresponding MSW loads of the province were obtained.

The following steps were taken to determine the distances between the main towns of the individual local municipalities and the towns where the sanitary landfills in the province were located: a list of the names of the main town in each NW local municipality was compiled and the shortest road distance between each town and the towns where sanitary landfills existed was established using a TomTom XXL global positioning satellite device. The routes followed had to be tarred and were either national or major provincial roads. The approximate travel time taken by trucks to transport waste from source to destination was computed using eqn (4).

$$\text{Time} = \frac{\text{Distance}}{\text{Average speed}} \tag{4}$$

Based on time taken for trucks to travel from a given town to towns that had sanitary landfills, the NW towns were grouped into time-based categories described in Table 1. This categorisation informed the process of planning and development of the logistics framework. Action taken for each category was based on guidelines provided by Cointreau [8], which are reflected in Table 1.

4 FINDINGS, DISCUSSION AND CONCLUSION

The study established that in the NW, waste collection, transportation and landfilling were the only value-adding activities undertaken in MSW management. The eight goals set in the PIWMP are yet to be achieved; there is an urgent need to integrate the principals of the WMH in the MSW management in the province. The WMH promotes reduction in waste generation by advocating for smart production processes; it could be integrated in MSW by introducing sorting at source and providing sorting centres as illustrated in Fig. 3. Sorting is beneficial as it identifies waste for reuse, recycling and that which could be used for energy recovery. Furthermore, sorting produces refuse-derived fuel (RDF), which may be used for energy production. Compared to unprocessed waste, RDF is a higher quality fuel and its use in energy production improves boiler performance [5]. The adoption of the use of RDF in energy production as part of the national strategy is a viable option; however, care must be taken to avoid combustion of RDF under unfavourable conditions as it may result in negative environmental consequences [24]. In view of the above, one can conclude that the *status quo* in the NW is unsustainable and that the province stands to benefit through re-engineering of SWM by providing collection services to all households and commercial enterprises and integrating the WMH. The model of the redesigned system that is proposed for adoption is illustrated in Fig. 3.

Table 1: Truck travel time (t) to nearest sanitary landfill and corresponding action.

Truck travel time (t)	Recommended action
$0 < t < 30$ minutes	Use compactor trucks ranging from 10 to 15 tonnes (T) to transport waste to the nearest sanitary landfills.
30 minutes $< t \leq 2$ hours	Establish transfer stations in those towns and use delivery trucks of 20T or more to deliver waste to the nearest sanitary landfills.
$t > 2$ hours	Select a town to serve as a collection point from where waste could be transported by rail to the nearest sanitary landfills.

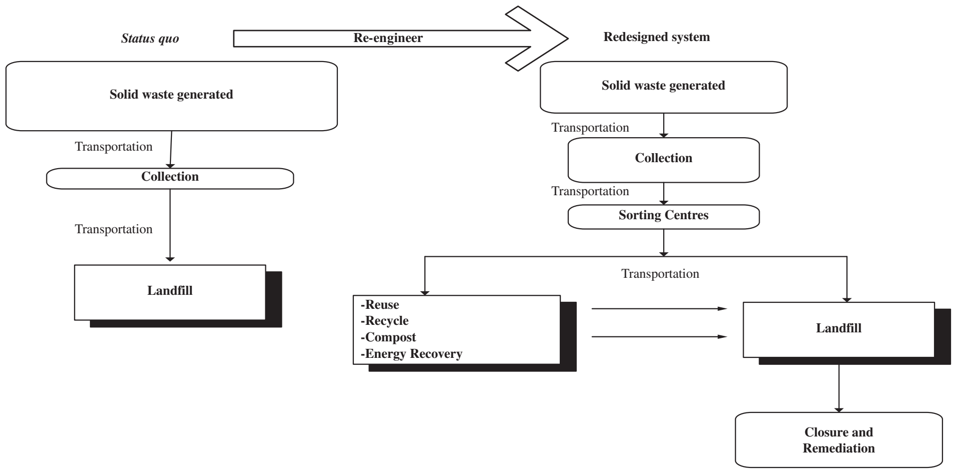

Figure 3: The redesigned system that includes value-adding activities in SWM.

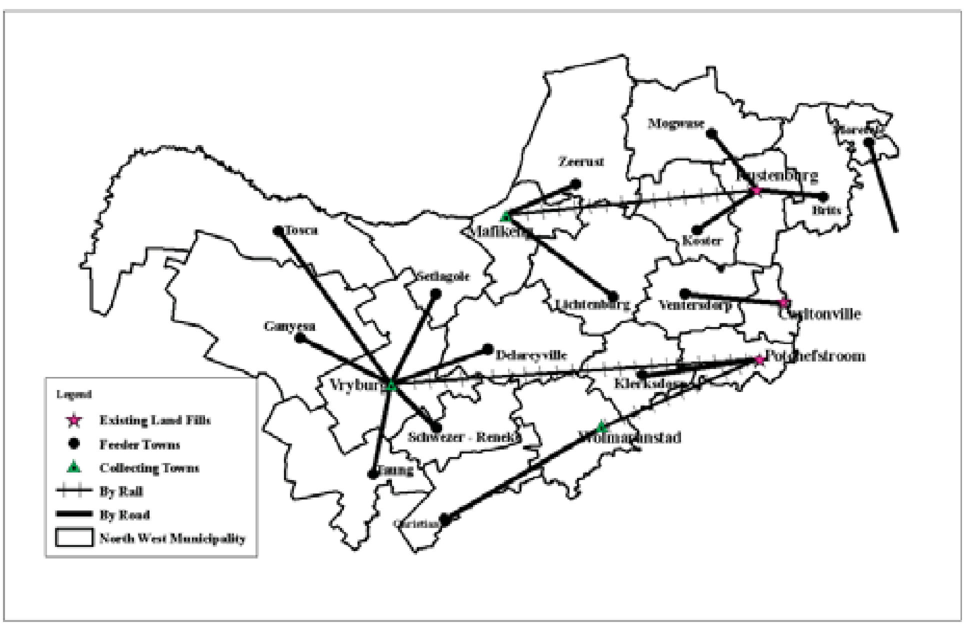

Figure 4: A logistics framework for transportation of MSW.

Advisably, sorting centres should be located close to landfills.

Furthermore, the logistics framework illustrated in Fig. 4 is proposed for bulk transportation of MSW in the NW province.

The positions of the towns in Fig. 4 were purposefully chosen for convenience and as such, they may not be true reflections of the actual positions of those towns. This framework accounts for all the local municipalities of the NW with the exception of Moretele. This particular local municipality is located on the north-eastern fringes of the NW and borders with Gauteng province. It is located about 4 hours' truck travel time from the nearest sanitary landfill in the province and is not connected to the existing national railway network. Rail haulage of MSW from Moretele should not be contemplated as it requires the construction of several kilometre of railway for the sole purpose of transporting a quantity of MSW that could never justify the capital outlay. As such, the most feasible option would be to transport MSW from Moretele by trucks to an appropriate sanitary landfill in Gauteng.

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